NELSON MANDELA UNIVERSITY

THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ELECTRICITY CONSUMPTION IN SOUTH AFRICA

BY

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In accordance with Rule G5.6.3, I hereby declare that the above-mentioned thesis is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

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ABSTRACT

In recent years, the relationship between electricity consumption and economic growth has been examined extensively in numerous countries. While there is high consensus in the scientific sphere on the interdependence between electricity consumption and economic growth, recent literature suggests that there are still competing views on the causal relationship between the two variables.

Energy has long been viewed as a vital driving force for economies. However, the crucial role that the energy sector has played during the industrial revolution allowed some authors to consider energy in the same way as the capital and labor factors in the production function. The energy factor is considered essential today in the process of development. Almost everyone agrees on the importance of its contribution to the process of growth and development by considering growth / energy model as an indicator of wealth and a vector to reduce social inequalities. Meanwhile, according to the different scenarios observed, energy consumption may or may not have impacts on economic growth or wealth creation. The problem of access to energy (electricity) in certain regions in Africa (and particularly in South Africa) remains one of the major challenges that require urgent attention over the coming decades. In addition, the lack of consensus among researchers has triggered a shift towards focusing on study methods and techniques used for investigations on the energy-growth nexus.

Using R programming for data analysis, this study investigates the asymmetric relationship between energy consumption and economic growth in South Africa by incorporating the following intermediary variables: trade openness, capital and labour. Results suggest that a conservation hypothesis is the most prevailing theory on the causal link between GDP and Energy Consumption in South Africa. This opinion is acknowledged as the growth-led electricity consumption opinion.

From an economic perspective, evidence from the research suggests that, without necessarily expanding energy accessibility, trade liberalisation and capital could generate clear gains to South Africa and efforts to promote and accelerate these initiatives should be encouraged. Given the often-competing resource limitation challenges faced by the South African government, as a result of prioritisation, trade

liberalisation should be favoured and be given roughly in the range of 1.5 times more attention than capital.

Therefore, South Africa may not necessarily need electricity for its economic growth. Although energy consumption has a major influence on economic growth, the latter could also possibly be achieved by increasing trade and/or capital, without any change in energy consumption. Energy conservation policies could be executed with little or no hostile effects on economic growth.

As a policy intervention, the research study recommends sustained efforts to strengthen regional integration with the view to achieving trade liberalisation, increasing capital formation and creating greater synergy for economic growth.

TABLE OF CONTENTS

CHAPTER 2

LITERATURE REVIEW

CHAPTER 3

METHODOLOGY

CHAPTER 4

DATA, EMPIRICAL ANAYSIS AND FINDINGS

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

LIST OF ANNEXURES

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

Abbreviations/Acronyms	Definitions
AIDS	Acquired Immunodeficiency Syndrome
ARDL	Auto-Regressive Distributed Lag
ASGISA	Accelerated and Shared Growth Initiatives of South Africa
COP21	Paris Climate Conference
CO2	Carbon Dioxide
CP	Current Policies
DRC	Democratic Republic of the Congo
EIA	Energy Information Administration
GEAR	Growth, Employment and Redistribution
GDP	Gross Domestic Product
GNI	Gross National Income
GT	Gigatonnes
GW	Gigawatts
HIV	Human Immunodeficiency Virus
IDC	Interest During Construction
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt Hour
M	Million
MDGs	Millennium Development Goals
MTBPS	Medium Term Budget Policy Statement
MW	Megawatts
NARDL	Nonlinear Auto-Regressive Distribution Lag

Abbreviations/Acronyms	Definitions
NERSA	National Energy Regulator of South Africa
NP	New Policies
OECD	Organisation for Economic Co-operation and Development
SA	South Africa
SDI	Special Development Initiatives
SETAs	Sector Education and Training Authorities
SMMEs	Small, Medium and Micro-Enterprises
SOEs	State Owned Enterprises
UK	United Kingdom
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States
VAR	Vector Auto-Regression
VECM	Vector Error Correction Model
WEO	World Energy Outlook

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

In recent decades, there has been tremendous pressure globally to compel policymakers to commit to initiatives that will mitigate effects of worldwide warming and climate change. The Paris Climate Conference (COP21) was held in December 2015 with the view to commit global leadership to a temperature increase below 2 degrees Celsius above the pre-industrial levels. Parties of the Paris Climate Conference also discovered the need to report progress on implementing their targets through a robust, transparent, and accountable system (Lu, 2016).

Still, for many countries, energy-saving policies somehow lead to a significant impact on economic growth; thereby affecting the general quality of life for the population (Lu, 2016). On a collective or national level, electricity consumption is strongly linked with economic development. Economic progress depends highly on energy inputs. Obviously, electricity consumption is strongly linked with the growth of real GDP. Consequently, there is a need to further investigate the relationship between electricity consumption and GDP growth in order to develop informed policies.

As an input to the production process, electricity is identified today as one of the vital driving forces of economic growth in all economies (Pokharel, 2007; Mulugeta, Hagos, Kruseman, Linderhof, Stoecker, Abraha, Yohannes, & Samuel, 2010). Given the large multiplier effect generated by electricity in the economy, it substantially adds to any growth in the economy through employment generation and leads directly to value contribution interrelated with extraction and transformation of inputs, technology transfers, marketing and distribution of goods and services (CDC Group, 2016). In addition to improving quality of life particularly through use of electrical appliances, heat and light, it also underpins reconstruction of out-of-date economic sectors and contributes to constant enlargement of secondary and tertiary sectors of the economy (Deloitte, 2017).

Meanwhile, with the growing demography on the African continent, energy deficiency is increasingly concerning. At the same time, there are many pressing commitments from the political sphere on the continent to alleviate poverty by substantially growing the economy. While there seems to be consensus that economic growth will alleviate poverty on the continent, the question how to grow the economy remains. On the other end, there seems to be strong indication of a close relationship amid economic growth and electricity demand. However, what remains uncertain is the subject of the connection (and hence, direction of causality) between electricity usage and economic growth. This has been subjected to numerous debates in the scientific sphere and remains unclear. This uncertainty is as a result of diverse approaches of analysis and different country characteristics (Adom, 2011) and the use of different data sets. Furthermore, the bivariate causality framework used in some studies may suffer from the oversight of variable bias (Altintas and Kum, 2010). This results from the fact that the direction of the relationship amongst the two variables and the scale of the approximations may substantially vary when a new third variable that links economic growth and electricity demand is introduced in the equation.

Ultimately, direction of causality will inform policies to accelerate economic growth. Like many developing countries, South Africa is reliant on electricity for its growing industrial sector (particularly mining, manufacturing, agro-processing and communication).

Historical data for the energy usage (measured in thousands kWh per capita) and economic growth (measured by real GDP per capita) in South Africa indicate a positive correlation (upward trend) over the period from 1980 to 2015; thereby suggesting the existing of causality between the two variables (Deloitte, 2017).

The overview of this study is to examine the asymmetric relationship between energy consumption and economic growth in South Africa by incorporating the electricity price, trade openness, capital and labour. In addition, the study examines the causal association between the considered variables and proposes a policy position for South Africa.

As such, this study starts with an introduction in Chapter 1. Chapter 2 reflects a systematic examination of the literature about the topic. Chapter 3 discusses the methodology and chapter 4 explores data, empirical analyses and findings. The study is completed in chapter 5 with conclusions and recommendations.

This study is quantitative in nature. Ethical considerations were strictly observed throughout this research in ensuring that:

- The risk of causing any harm is minimised.
- Informed consent is obtained from the relevant authority prior to using any sensitive materials / data.
- Research data would be protected at all stages of the process from collection to publication.
- Deceptive practices that could manipulate the research outcome would be avoided.
- Avoid plagiarism.

1.2 THE GLOBAL ENERGY SITUATION

The International Energy Agency (IEA) published its annual report World Energy Outlook (WEO) in November 2014, establishing the different scenarios for energy policies until 2040 (https://www.iea.org/weo/). In addition to the scenarios presented, reflections were made in order to draw lessons from the ongoing future energy evolutions. Adapting a robust approach in combatting climate change was a major resolution that was taken from the various reflections.

In addition to the global energy trends, this report also introduces prospects for nuclear energy globally and in sub-Saharan Africa. The different scenarios envisaged by the WEO (2014) by 2040 are the following:

- A central scenario, called "New Policies" (NP), which considers commitments to reduce greenhouse gases; in particular, following the 2010 Cancun Agreements.
- A trend scenario, called "Current Policies" (CP), which describes the evolution of global energy markets by considering only the policies in force.
- A "450" scenario proposing an evolution of the world energy system that would mitigate greenhouse gas emissions with the view to limit global warming at 2 ° C (compared to the pre-industrial era).

These scenarios admit certain technological and macroeconomic hypotheses such as those on oil prices, for example ($ 132 / bl in 2040 for the NP, then 155 dollars / bl for CP and finally 100 dollars / bl for scenario 450). In this context, the reflections made by the WEO (2014) on the world energy system, are as follows:

- Despite a significant slowdown (+ 1% per year after 2025, compared to more than 2% per year over the last 20 years), global energy demand should in this case grow by 37% by 2040 in the central scenario, mainly outside OECD and China.
- In terms of the IPCC (Intergovernmental Panel on Climate Change), the CO^2 emissions budget that the planet can tolerate without too much damage would be 2300 GT (gigatonnes), and the planet currently only need an additional 1000 GT to meet this threshold. If current trends continue, such a threshold shall be met by 2040.
- Meanwhile, even when considering the best-case scenario (central scenario), the evolution of policies and market pressures tend to reduce the share of fossil fuels at a level of 75% of the world's energy mix, compared with 82% currently.
- In this perspective, investment required to achieve the best-case scenario will be in the range of a cumulative amount of 40 trillion US dollars by 2035.
- However, in order to limit global warming to 2 ° C, the IEA estimates that $ 1.6 trillion a year should be invested in low carbon technologies compared to 0.9 trillion in the central scenario.
- Fossil fuel subsidies accounted for 550 billion US dollars for only the year 2013, more than four times the amount of subsidies allocated to renewable energies. At the same time, in the Middle East, nearly 2 Million barrels of fuel are used daily to produce electricity. Yet, without any subsidies, this required electricity could be produced by renewable energies at very competitive price.
- Electricity is indeed considered as the most sought-after form of energy with a need for additional capacity estimated at 7200 GW by 2040 while, paradoxically, 40% of global power plants (all technologies combined) need major upgrades.
- It is further estimated that, by 2040, renewable energies (hydroelectricity, wind, solar, and others) will cover a third of global electricity production supply.

- Moreover, the world's nuclear power capacity is expected to grow by 60% by 2040 in the central scenario, exceeding 620 GW; which includes an additional capacity of 130GW, 32 GW and 19 GW respectively for China, India and Russia. Meanwhile, a decline of 18 GW is anticipated in Europe.
- From the 434 reactors that were operational across the world by the end of 2013, 200 should be shut down by 2040, especially in Europe, in the United States and in Japan. At first glance, the IEA estimates an amount of 100 billion US dollars for dismantling these reactors.
- The EIA estimates that 620 million people are without electricity in sub-Saharan Africa and nearly 730 million use biomass for cooking. This leads to air pollution and subsequently causes nearly 600,000 premature deaths a year.
- It is further estimated that, based on the central scenario, nearly one billion inhabitants in sub-Saharan Africa will access electricity by 2040.
- Despite its large potential in energy resources, sub-Saharan Africa remains vulnerable in terms of access to energy services. Hence the IEA advocates for three sets of strategies in order to address this paradox: invest in the distribution of electricity, develop cooperation at regional level, and optimise funding in infrastructure development.
- As a result of these sets of strategy, it has been proven that the cost paid by consumers for energy will substantially increase all over the world; except in the United States and India.

The total global energy consumption in 2012 was around 9 billion tons of oil equivalents. To achieve this, a production of almost 13.4 million of primary energy was required. Global energy consumption has considerably evolved in different regions. According to the IEA, between 1973 and 2012, global energy consumption almost doubled.

Figure 1.1 below depicts the Energy Transformation Cycle.

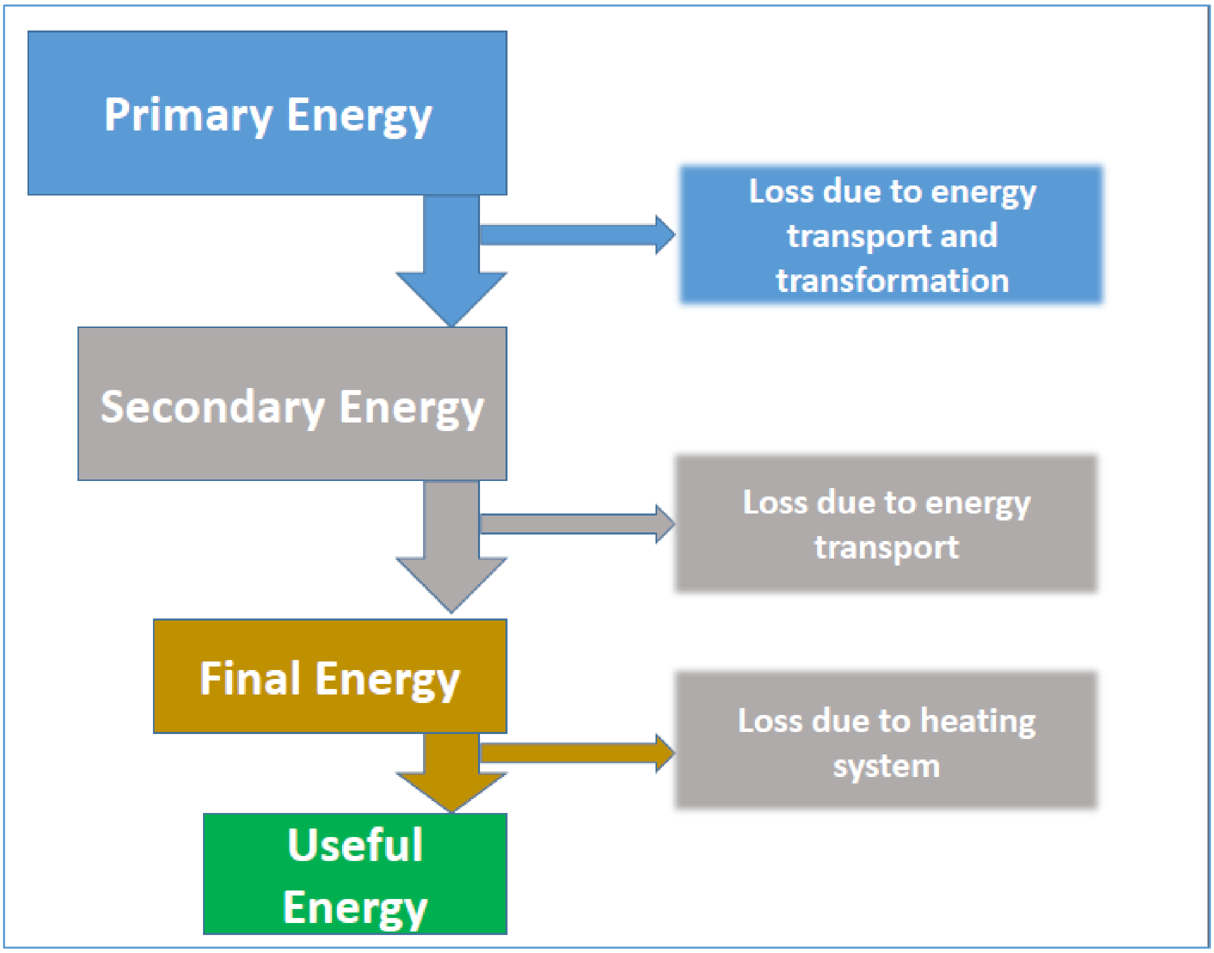


Figure 1.1: Energy transformation cycle (IEA, 2015)

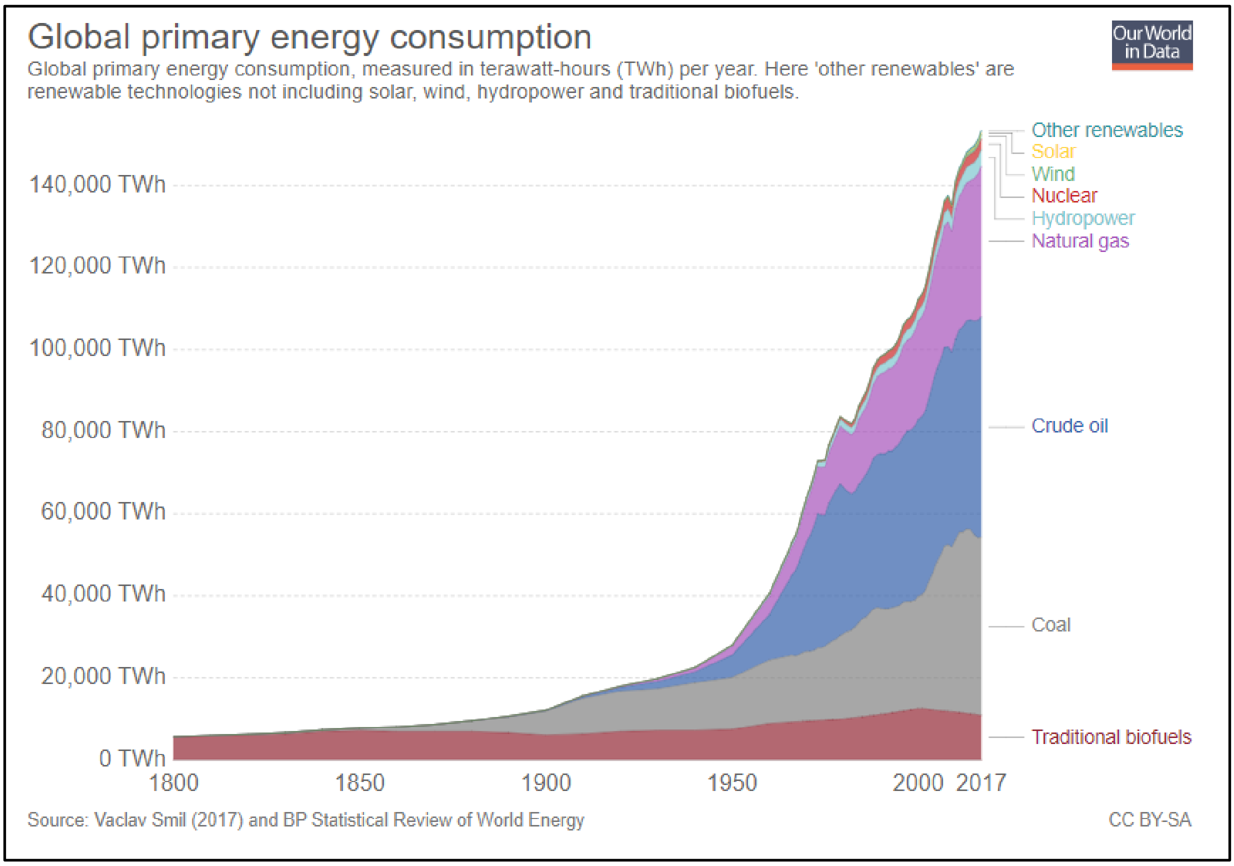


Figure 1.2: Global energy consumption (IEA, 2015)

Table 1.1: Production and consumption of energy in million tons of oil equivalent (EIA, 2015)

	1990		2013		Consumption variation 2013/1990
	Primary production	Consumption	Primary production	Consumption	
Petrol	3 241	2 606	4 216	3 716	43,00%
Natural Gas	1 688	944	2 909	1 401	48,00%
Coal	2 225	766	3 958	1 069	40,00%
Nuclear	526		646		
Hydroelectricity	184		326		
Wind, solar, geothermal	37	3	162	34	
Biomass	905	792	1 376	1 130	43,00%
Electricity		834		1 677	101,00%
Heat		335	2	273	-19,00%
Total	8 806	6 281	13 594	9 301	48,00%

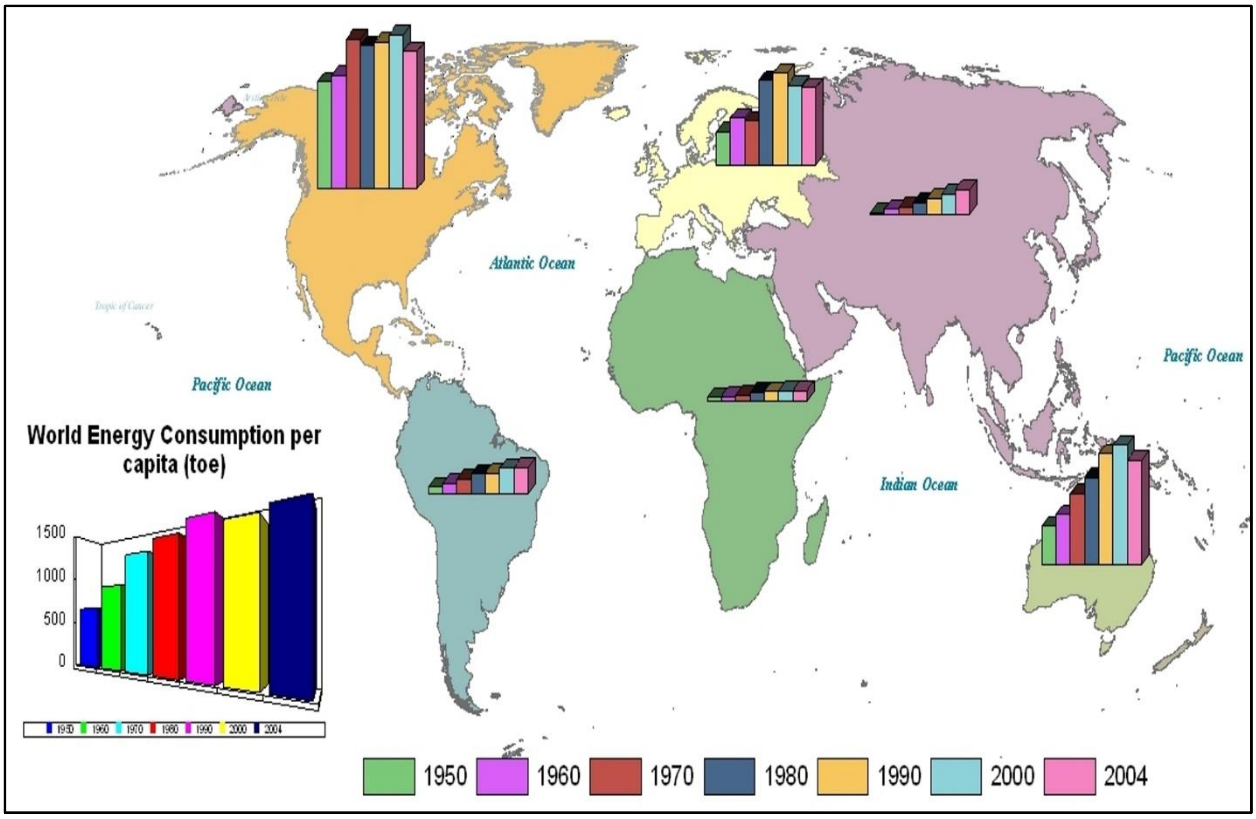


Figure 1.3: Global energy consumption per region (EIA, 2015)

1.3 THE GLOBAL COMPETING VIEW ON THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ELECTRICITY CONSUMPTION

In recent years, the relationship between electricity consumption and economic growth has been examined extensively in numerous countries (Odhiambo, 2010; Payne, 2010; Ozturk, Aslan & Kalyoncu l, 2010; Apergis and Payne, 2010). While there is high consensus in the scientific sphere on the interdependence between electricity consumption and economic growth, recent literature suggests that there are still four competing views on the causal relationship between the two variables (Inglesi-Lotz and Pouris, 2014.).

The first view is that electricity consumption Granger-causes economic growth. This means that economic growth is dependent on electricity consumption. Alternatively, a decrease in electricity consumption would perhaps result in a negative effect on economic evolution (Narayan and Singh, 2007; Odhiambo, 2010). This is also referred to as a growth hypothesis in some literature (Inglesi-Lotz and Pouris, 2014).

The second view, however, maintains that economic growth is the main driver of electricity usage. This view is known as the growth-led electricity consumption view. In this case, it is believed that electricity demand is driven mostly by the economic growth of the real sector. Therefore, a country may not necessarily need electricity for its economic growth. Hence, energy conservation policies could be implemented with little or no adverse effects on economic growth. This is known in some literature as conservation hypothesis (Inglesi-Lotz and Pouris, 2014).

The third opinion, which may be observed as the middle ground, postulates that both electricity usage and economic growth Granger-cause one another. In other words, there is a bidirectional relationship between electricity consumption and economic growth. This is known as feedback hypothesis (Inglesi-Lotz and Pouris, 2014).

The fourth and last view is referred to as a Neutrality hypothesis (Inglesi-Lotz and Pouris, 2014). This is based on the ground that there is no connection amongst the two variables. Electricity conservation policies will have no effect on economic growth and improving economic growth will not influence electricity usage.

A survey conducted revealed that 29.2% of the results supported the neutrality hypothesis, 28.2% the feedback hypothesis, 23.1% the growth hypothesis and only 19.5% the conservation hypothesis (Mulugeta et al., 2012). On the other end, a survey from Payne (2010a) suggests approximately similar trends: 31.5% supported the neutrality theory, 27.87% the conservation theory, 22.95% the growth hypothesis and 18.03% the feedback hypothesis (Mulugeta et al., 2012). However, in general, research has failed to reach consensus on the trend of the causality since results remain largely inconclusive (Khobai, Mugano & Le Roux, 2017).

The existence of the four competing views on the causal relationship between electricity consumption and economic growth motivates for further examination of this matter in the case of South Africa by incorporating the following additional variables: electricity price, trade openness, capital and labour. Thus far, research undertaken in South Africa has inclined to focus on the bivariate context, which has been largely criticised due to oversight of related variables (Narayan and Smyth, 2005). There has been no study conducted in SA that has incorporated these variables. To address the shortcomings, electricity prices, trade openness, employment and capital have now been considered for incorporation into the study with the view to improve reliability of results.

Trade openness encompasses the transmission of goods produced in one country to another, either for additional processing or for the purposes of using the resources (Shahbaz, Jalil, and Islam, 2010). Acceptable electricity supply is then key for producing the goods being moved from one country to another. Trade openness similarly has an effect on electricity supply. Meanwhile electricity is too a commodity, its production can be made efficient if some of the resources used in its production process can be simply moved from one nation to another.

Bildirici, Bakirtas and Kayıkçı (2012) debate whether high electricity prices have negative impacts on economic growth. As electricity enhances quality of life and production, higher prices will force consumers to reduce consumption; thereby potentially compromising production and quality of life of households. Some authors argue that increasing the electricity tariff will increase prices, which will subsequently escalate sales prices and product costs; thereby affecting competitiveness in the wider market.

Labour has been included as an intermittent variable in many studies, due to its positive influence on economic development and electricity supply, to prove the correlations amongst employment, electricity supply, and economic growth (Ellahai, 2011; Ghosh, 2011). In the end, Narayan and Singh (2007) establish that employment Granger-causes economic growth. Meanwhile, studies from Narayan and Smith (2005), and Gurgul and Lach (2012) suggest a unidirectional connection from electricity usage to economic growth and bidirectional connection between electricity usage and economic growth, respectively.

In economic theory, capital formation refers to the total stock of capital that has been formed in future production of goods. In this case, it refers to additional capital goods created in order to escalate the production of electricity in a nation. Studies suggested that capital Granger-causes economic growth (Ellahai, 2011; Shabhaz et al., 2011; Adebola, 2011). Additionally, in a study by Lee, Chang and Chen (2008), a feedback hypothesis was also revealed between capital and economic growth as well as between capital and energy consumption. There is therefore a strong indication that capital will have a positive and a long-term impact on both economic growth and electricity supply in South Africa.

1.4 ENERGY CONSUMPTION PROFILE IN AFRICA

1.4.1 Demography and energy consumption

The African population will cross the 2 billion mark by 2050, which will represent 25% of the world population, against 15% currently. This demographic boom will lead, on the one hand, to numerous opportunities; and, on the other hand, enormous challenges. It should be noted, however, that there would be a major disparity in population growth across the different regions of the continent. The two major regional centres that will record substantial population growth will be the Eastern and Western part of the continent. The Northern and Southern part of the continent will record a moderate growth. Moreover, the demography growth will make Africa the most attractive continent in terms of consumer market, production, investment and energy policies. Furthermore, these factors could constitute a lever to massive youth employment and to assist in reducing over-reliance on the outside world. In addition, this demographic explosion will increase consumption that will result in greater production and investment. The diversity of natural resources of the continent and its demography shall therefore constitute the backbone of energy transition as well as demographic and economic policies that will allow the continent to adopt innovative ways of solving problems.

Nowadays, it is increasingly clear that if the continent wants to reach the Millennium Development Goals (MDGs), a reliable and efficient system of regular supply of electricity is now compelling. While the demographic boom is viewed as a greater asset in terms of consumption and labour markets (potential market), it however exacerbates issue such as access to education, health and energy. Energy could be a major factor to eradicate problems related to health, education, agriculture, livestock breeding, trade, transport, etcetera. Despite its vast diversity in natural resources and demographic boom, Africa is still the continent with the lowest level of GDP, with a poor supply of energy. Between 1980 and 2010, electricity consumption in Africa was multiplied by 2.3, while the GDP has only multiplied by 1.6. In addition, the Eastern and Western regions of the continent are considered the most affected by these two phenomena: energy deficit and population explosion. According to the economic prospects in Africa in 2015, primary energy demand in sub-Saharan Africa increased by around 45% between 2000 and 2012. However, GDP grew by only 22%, which corresponds to a rate half of Energy demand. Generally, an additional point in GDP should correspond to an increase of half a point in primary energy demand. Moreover, in developing countries, the link between energy consumption and GDP growth is significantly narrow. Average final energy consumption per capita in Africa was 0.50 tons of oil equivalent (toe) / year while the global average was 1.6 toe / year in 2009. As such, it is therefore essential to study the model growth / energy, in order to develop lasting solutions that will allow the continent to meet its future energy requirements.

1.4.2 The need for new strategy for the continent

Africa needs innovative development strategies for this 21st century. African economies cannot simply reproduce the old economic transition models that often collide with external obstacles that are unique to the continent. Currently, Africa needs unprecedented strategies, combining the benefits of different sectoral approaches traditionally advocated with the view to take advantage of its own demographic and geographical characteristics. Without doubt, this would allow the continent to develop innovative and unique policies for its economic and social transformation (UNESCO / UNECA / UNDP, yyyy). Some proposed policies are:

- initiate significant changes in production and modes of energy consumption in Africa;
- implement new reform on the exploitation of potential available resources.

These strategies would ensure a unique African energy transition; and ultimately, propel the continent towards sustainable development.

1.4.3 Energy supply in Africa

The adequacy of the energy supply should be a pre-requisite for economic and social development, knowing that energy demand increases with rising household incomes. Numerous African countries have adopted new policies to improve their energy supply and address deficits. These new policies adopted have not always yielded desired benefits. Some countries (e.g. Morocco, Mali, Senegal, South Africa) have certainly increased the production capacities but such increases remain insufficient or even inefficient to meet the growing demand for energy. In sub-Saharan Africa, coal-fired power plants accounted for 45% of total sub-Saharan Africa energy installed capacity (mainly in South Africa), compared to 22% for hydro-electricity and 17% for oil-fired power plants (these two energy sources being better distributed), 14% for gas-fired plants (mainly in Nigeria), 2% for nuclear and less than 1% for renewable energies. These figures show unambiguously the marginal share of renewable energies in the process of energy production in Africa. Ironically, this form of energy is proved to be the most cost effective on the continent according to various researchers.

Despite the colossal means injected into the energy sector, Africa is still not producing enough electricity. Until recently, there seemed to be misalignment between energy policies at the national and regional levels. However, sub-regional cooperation should make it possible to serve larger markets. Industrial activities generated through mining and refineries account for half of electricity consumption in sub-Saharan Africa. However, most of it is concentrated in South Africa, Ghana, Mozambique and Nigeria. The residential sector accounts for only 27% of the total consumption since the level of household electrical equipment is relatively low and disposable income is quite limited. The telecommunications boom and mobile phones have been causing a rise in demand of energy in recent years; not only on the continent but also in other parts of the world.

1.5 THE SOUTH AFRICAN CONTEXT:

Like many developing countries, South Africa is reliant on on electricity for its growing industrial sector (particularly mining, manufacturing, agro-processing and communication). Historical data related to electricity usage (measured in thousands kWh per capita) and economic growth (measured by real GDP per capita) in South Africa indicate a positive correlation (upward trend); thereby suggesting the existence of causality between the two variables.

The electricity industry in South Africa is crucial because it contributes to a large percentage of the country's Gross Domestic Product (GDP) (Department of Energy, 2018). In 2007/2008 South Africa encountered an energy crisis, which had a negative effect not only on the electricity industry itself, but also on the economy (World Bank

2018). As a result of this, research in this field has increased substantially over the years. This indeed sparked some debate within the academic circles, on whether there really exists a nexus between economic growth and electricity consumption (Squalli, 2007, Apergis and Payne, 2011, Noh and Masih, 2017, Wolde-Rufael, 2009; Adebola, et al, 2016).

The state-owned monopoly utility, Eskom, manages and controls electricity supply in South Africa. The country largely depends on various state-owned enterprises for electricity supply, rail and port operations, defence and telecommunications. The various SOEs have significantly contributed to the development of the economy while at the same time they have remained troubled by structural and operational complications (Fourie, 2014). Eskom largely dominates the current electricity distribution structures in South Africa, but some distributions are done by the municipalities. This model has been criticised for allowing excessive government intervention in the electricity supply chain; thereby opening doors to malpractice and inefficiencies. Hence the increasing call to shift towards private sector participation in the electricity supply chain (Khobai, Mugano & Le Roux, 2017).

Since the end of apartheid, there has been a substantial growth in electricity demand in South Africa. As the country abolished its discriminatory policies and adopted an open market strategy, there have been many new entrants into the active economy, of people who were mostly previously disadvantaged. As a result, electricity supply could not match the increasing demand; forcing the government (through Eskom) to develop a major electricity expansion programme with the view to substantially increase national supply (Khobai et al., 2017).

In 2005, Eskom's electricity expansion programme was rolled out with the view to raise its transmission line by 4700km while the generation capacity would increase by 17120 MW. The objective of the programme was to meet the increasing demand at the time, also to diversify energy sources. The cost of the programme has substantially escalated year on year. By 2013, the programme was estimated to cost R 385 billion and it is now projected to cost over a R 1 trillion or more by 2026, with a projected double capacity (80,000MW). Currently, the amount of additional capacity installed is 5,500MW, in addition to existing capacity of 39,794MW (Botes, 2012). As a result of the escalating construction costs of power stations, the price of electricity for household consumers went up by 137% in 2011, mainly due to the approval of the resourceful Medupi flagship project. Later on, an additional 25% increase on tariff was proposed by Eskom to finance Kusile power station (Khobai et al., 2017). These increases are listed below:

i. *"In March 2006, the expansion of 1800 MW budget price increased from R17 billion to R20 billion which is between R9.4 m/MW and R11.1 m/MW on average.*
ii. *In January 2007, the Medupi power station size was changed to 4500 MW, costing over R52 billion and the first unit was reported to be commissioned in mid-2011.*
iii. *In February 2007, the price was confirmed to be R56 billion (which is equivalent to R12.44 m/MW on average) and delayed by 1½ years.*
iv. *Late February 2007, the budget was announced to have increased to R70 billion but was confirmed to cost R66 billion (an equivalent of R14.67 m/MW on average) in May.*
v. *In October 2007, the station was announced to have expanded to 4700 and then to 4800 in the same month, with the cost increasing to R78.66 billion (equivalent of R16.37 m/MW on average). The first unit was then to be commissioned to the third quarter of 2011, a delay of 2 years.*
vi. *As of March 2011, the budget increased to R120 billion from R78.6 billion in October 2007. The date of commissioning the power station was postponed to June 2012, a delay of 2½ years, with a budget price equivalent to R26.15 m/MW.*
vii. *In July 2012, the size was 4764 MW, costing R91.2 billion excluding interest during construction (IDC). The commission date was postponed to December 2013. By December 2013, it was projected that the power station would cost R130 billion including IDC. This is now gone to 3 years." (Khobai et al., 2017)*

The persistent delays and changes in scope had a negative impact on the national economy and led to major additional cost implications on the various projects. Unfortunately, such major cost implications are then passed to consumers predominantly through electricity tariffs / prices. As such, many observers in South Africa have called for a thorough investigation into the relationship between electricity prices and economic growth in South Africa with the view to come up with the correct and appropriate price regime that will support economic growth.

As a result, research in this field has increased substantially in South Africa. Eskom continuously applied for further electricity price increases over the past decade. This has sparked arguments on how increases in electricity prices distress the energy sector and the economy at large. Debates among policy-makers, academics, industrialists and other various stakeholders in the country rotate, firstly, around the association between energy demand and economic growth (which one affects which), and secondly, the factors of energy demand. Both topics prove to be of particular importance for the forecasting of energy demand through the decisions that have been made on policy.

Since 2007, various investigations have dealt with the case of South African (Inglesi-Lotz and Pouris, 2014). These studies have observed the association amid the country's electricity usage and economic growth, either individually in a time-series context or in a panel data framework together with other countries. In terms of the South African case, the conclusions of the studies differ substantially. For instance, Al-Mulali and Binti Che Sab (2012) and Eggoh, Bangake and Rault (2011) confirm that energy usage results in economic growth, whereas Esso (2010) established exactly the opposite. Interestingly, Kahsai et al. (2012) found that there exists no relationship in the short run (neutrality hypothesis), but a bidirectional causality exists in the long run (feedback hypothesis). In most cases, a Granger causation test was used by estimating vector auto-regressive (VAR) models (Inglesi-Lotz and Pouris, 2014).

On the other hand, studies have explained several different possible causes of relationship between economic growth and electricity consumption such as electricity prices, trade openness, labour and capital. These variables are proved to be very significant to economic growth and electricity consumption in the South African context (Inglesi-Lotz and Pouris, 2014). For instance, these interim variables can affect the general need for money and spending patterns. The more money is needed, the more likely people are to spend less, consume less electricity, and even do more with less by introducing recent technology and cutting labour costs. Also high trade openness will significantly motivate for maximum production. Consequently, there are many complex scenarios that lead to an asymmetric relationship depending on which interim variables are used.

This paper intends to investigate the non-linear and asymmetric relationship between energy consumption and economic growth by incorporating electricity price, trade openness, capital and labour.

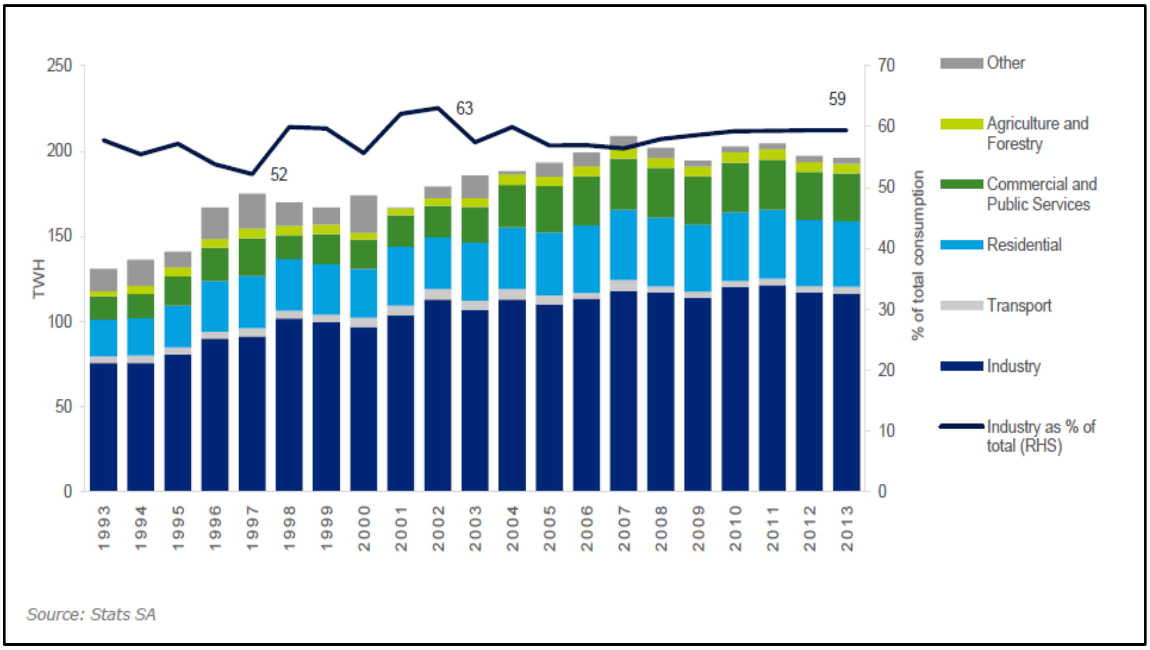


Figure 1.4: Trends in electricity consumption in South Africa by customer category, 1993-2013 (Deloitte, 2017)

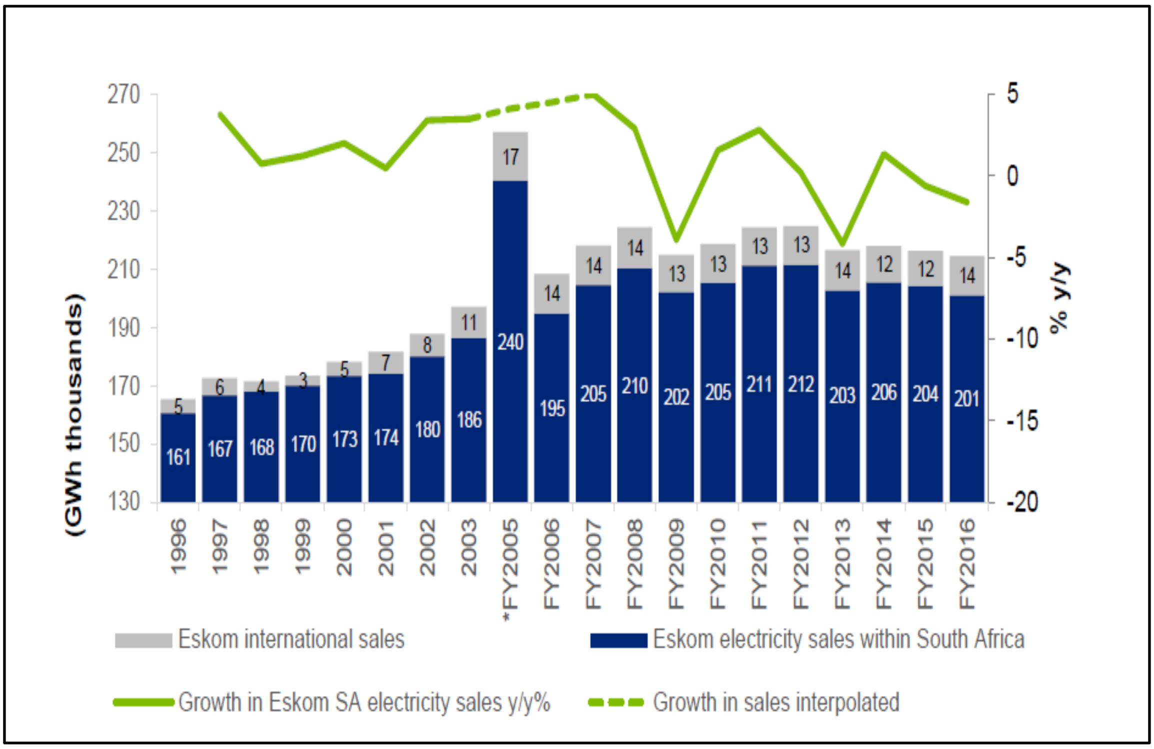


Figure 1.5: Historical trend in electricity sales in South Africa, GWh, 1996 to 2016 (Deloitte, 2017)

1.6 RESEARCH PROBLEM STATEMENT

Most existing studies on the causal relationship between economic growth and energy consumption have, to date, focused mainly on a symmetric co-integrating relationship, and have ignored the possibility of an asymmetric co-integrating relationship. This remains a major gap to be filled in in the economic growth and energy consumption literature for South Africa.

Furthermore, in sub-Saharan African countries, literature that has investigated the relationship between economic growth and electricity consumption is limited, except for a few (Samuel and Lionel, 2013, Nyasha and Odhiambo, 2015, Akinwale, Jesuleye, & Siyanbola, 2013, Kananura, 2015; Adebola et al, 2013). In South Africa, studies have looked at the relationship between electricity consumption and economic growth using the ARDL (Auto-Regressive Distribution Lag) model (Asongu, El Montasser, G. & Toumi, 2016, Khobai et al., 2017). However, this studyaims to enhance the findings of previous studies and investigate the relationship between economic growth and electricity consumption in South Africa. Therefore, unlike the majority of the previous studies, this study will use the recent NARDL (Nonlinear Auto-Regressive Distribution

Lag) model that takes into consideration nonlinear and asymmetric co-integration between variables (Shin, Yu & Greenwood-nimmo, 2014).

1.7 HYPOTHESES OF THE STUDY

The study investigates the asymmetric relationship between energy consumption and economic growth in South Africa. The non-linear autoregressive distributed lag bounds testing approach is applied to examine the asymmetric co-integration between the variables.

1.8 RATIONALE OF THE STUDY

The research enhances our understanding on the relationship between economic growth and electricity consumption in South Africa. The findings have important implications for companies, advisors, investors, the National Energy Regulator of South Africa (NERSA) and the South African government as a whole. This study is therefore a useful tool for policy formulation, evaluation and prescription. Furthermore, this study also helps stimulate further debate and interest among academics and practitioners in this field.

1.9 PURPOSE / AIM OF THE RESEARCH

The main aim of the study is to investigate the asymmetric relationship between energy consumption and economic growth in South Africa a using non-linear autoregressive distributed lag bounds approach.

1.9.1 Research Objectives

In order to achieve this aim, the following objectives were set:

- To investigate the asymmetric relationship between energy consumption and economic growth by incorporating electricity price, trade openness, capital and labour;
- To examine the causal association between the considered variables; and
- To propose a policy position in South Africa in line with the study.

1.9.2 Research Questions

In order to address the above research objectives, data used specifically aims at answering the following research questions:

- By incorporating electricity price, trade openness, capital and labour, is there any asymmetric relationship between economic growth and electricity consumption in South Africa?
- What is the causal association between the considered variables?
- What are the policy interventions that could be derived from this study?

1.10 LIMITATIONS OF THE STUDY

The four interim variables were selected from the intense literature review conducted and these interim variables may not be exhaustive to sufficiently unpack and understand the relationship between GDP and electricity consumption. The current study is limited to four variables, yet in reality, there might be many other factors that are susceptible to influence the relationship between the two variables of interest. In addition, it was further established during the study that reliable data on electricity prices for the full period covered during the study were not available. Hence, the electricity price was therefore omitted from the study and this may subsequently reduce reliability of results.

1.11 SUMMARY

This chapter introduced the concepts of economic growth and electricity consumption within the global and South African context. The chapter started with an overview highlighting the vital role played by electricity in all economies. It emphasised its large multiplier effect generated through its contribution to the enlargement of the primary, secondary and tertiary sectors of the economy. The chapter further discussed global energy trends and scenarios; and highlighted the competing view on the relationship between economic growth and electricity consumption. Focus on the chapter was then narrowed on the energy consumption profile in Africa by looking at demography, energy consumption, the need for new strategy for the continent, energy supply, and finally looking particularly at the South African context.

It is against this background that a research problem statement, hypothesis of the study, rationale of the study, purpose, aim and objectives of the research as well as limitations were established and articulated.

. In the next chapter, a review of existing literature on the relationship between economic growth and electricity consumption is explored. Chapter 3 will focus on the research methodology while in chapter 4 the findings of the study are presented. The last chapter will conclude the study and make some recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews literature. The literature explores the relationship between economic growth and electricity consumption in the context of South African, looks at certain regions in Africa, as well as presents global views. This chapter also highlights the relevant economic models used to establish the relationship between economic growth and electricity consumption. The literature that shows evidence on previous studies on this topic is also presented in this section. Furthermore, the literature enriches the mind and assist in terms of choosing the correct and proper variables for this research study. The study can be considered to be relevant to the context of South Africa, because, energy has been veed as a vital driving force for economies and considered essential today in the process of development. The last part concludes the chapter.

2.2 LITERATURE REVIEW

Increasing modernisation of economies and industrialisation drive demand for electricity (Khobai, 2017). Electricity in turn, increases the standard of living and it is widely recognised as an important factor for infrastructure development (Masuduzzaman, 2013). Many researchers have investigated the causal relationship between energy consumption and economic growth over the past decades owing to the importance of electricity usage on economic growth and development.

Moreover, recent growing concerns regarding climate change have further prompted the interests of many researchers to examine the relationship between electricity consumption and growth in the economy (Fei, Rasiah & Leow, 2014). Since the 1970s, there has been somewhat a lack of consensus on the causes of the electricity-growth nexus as new results have continued to occur from empirical studies of this relationship (Payne, 2010). Narayan and Prasad (2008) specify that two thirds of accessible studies published in Energy Policy and Energy Economics conclude a unidirectional Granger causality running from electricity usage to economic growth in both developed and developing nations. In other words, most countries' economies are reliant on electricity supply to support social developments (Murry and Nan, 1996; Wolde-Rufael, 2006; Chen et al., 2007; Narayan and Prasad, 2008).

On the other hand, some literature sources suggest that research on electricity supply is sparse (Khobai et al., 2017). There have been few attempts to apply the causality framework by investigating whether electricity supply stimulates economic growth or vice versa (Yoo & Kim, 2006). A bivariate study by Yoo and Kim (2006) revealed a one-way causality flowing from economic growth to electricity generation without any feedback effect in Indonesia. In other words, increases in electricity consumption from the household sector in Indonesia is attributed to high income for citizens, which in turn is the result of economic growth (Khobai et al., 2017). Also, economic growth increases enhanced the industrial sector's usage of electricity; thereby resulting in increasing production (Khobai et al., 2017). Hence there is the strong drive to generate more electricity in Indonesia. Bayraktutan, Yilgor and Ucak (2011) conducted an exploratory study on the relationship between renewable resources and economic growth based on data covering a period between 1980 and 2007 in OECD countries. Consequences revealed a long-term causality between renewable electricity generation and economic growth. In conclusion, the study emphasised the need to come up with strategies and policies that support investment in electricity generation from renewable resources in order to further grow the economy.

In Sri Lanka, a study based on Yang's regression analysis led by Morimoto and Hope (2004) discovered that power supply had a progressive contribution on economic growth. Another bivariate causality investigation using the VAR model on the connection between electricity supply and growth in the economy conducted by Sarker (2010) on Bangladesh, indicated a one-way causality flowing from electricity supply to economic growth. This suggests a need to implement policies that will contribute to the enhancement of electricity supply in Bangladesh. A trivariate framework study conducted by Ghosh (2009) on India using an auto-regressive distributed lag (ARDL) bounds testing framework for the period 1970 to 2006 only supported a long-term and short-run Granger-causality flowing from real GDP and electricity supply to employment. There was no causality found flowing from electricity supply to economic growth; thus suggesting that energy conservation measures could be applied in India without affecting economic growth (Khobai et al., 2017).

A study by Lean and Russel (2010) to inspect the link between economic growth, energy generation, exports and prices presented no causal relationship amid export and economic growth, nor between prices and economic growth. Moreover, a unidirectional causality flowing from growth in the economy to power supply was recognised.

Another multivariate framework research study by Ellahai (2011) using the autoregressive distributed lag (ARDL) bounds test discovered existence of both long- and short-run relationships amid energy supply, economic growth, industrial sector development, capital and labour in Pakistan. This should motivate the Pakistan government to contemplate increasing their electricity supply in an efficient way, using it as an incentive to improve their industrial sector in order to boost economic growth. Furthermore, results suggested that additional electricity generating plants are likely to create more employment.

In Portugal, Cerdeira (2012) confirmed the unidirectional relationship flowing from renewable electricity generation to foreign direct investment in the short-term. The results further showed a bidirectional causality amongst renewable electricity generation, real income, inward foreign direct investment as well as population.

Employing data for the period 1971 to 2009, Nnaji, Chukwu and Nnaji (2013) carried out a study in Nigeria to estimate the co-integration and Granger-causality relationship between economic growth, electricity supply, fossil fuel consumption and CO2 emissions. Findings disclose that there exists a long-term relationship between these variables. Electricity supply was also found to be positively related to CO^2 emissions. The Granger-causality results suggested that a weak connection existed from energy supply to economic growth. Therefore, this means that focus should shift towards electricity supply improvement to ensure that economic growth is enhanced in Nigeria.

Samuel and Lionel (2013) conducted another study on electricity supply in Nigeria using the ordinary least squares model in the context of Error Correction Mechanism with the view to examine the relationship between economic growth and energy supply. Results from the annual time series data revealed that, in addition to electricity supply, technology and capital similarly play a crucial role in the development of the economy. This is the root of the recommendation on investing further in technology in order to reduce power outages and ultimately enhance economic growth.

In Angola, a study for the period 1971 to 2009 by Adebola and Shahbaz (2013) confirmed the presence of long-term co-integration between electricity usage, economic growth and urbanisation. Furthermore, the findings illustrated bidirectional causality between electricity consumption and economic growth. This suggests that, given the importance of electricity in Angola, policies geared towards the improvement of the electricity industry should be encouraged. Adebola et al. (2016) further established similar findings from a different study on Angola.

An assessment in Portugal by Shahbaz et al. (2011) revealed that the long-term causality established feedback hypotheses on all the variables except Granger-causality between electricityusage and economic growth. Meanwhile, over the short-term, all variables proved bidirectional Granger-causality. A unidirectional Granger-causality flowing from economic growth to electricity consumption was also established in Portugal through this study. Moreover, findings from a study by Gurgul and Lach (2012) on Portugal opposed this view and found bidirectional causality among aggregate electricity usage and GDP as well as between employment and aggregate electricity usage. At disaggregated levels, a neutral theory was established between industrial energy consumption and economic growth and a unidirectional causality moving from industrial energy consumption to GDP was revealed (Khobai, 2017).

In Cote d'Ivoire, Kouakou (2011) discovered the Granger-causality relationship between electricity usage per capita and economic growth using their data for the period from 1971 to 2008 (Khobai, 2017). The findings portrayed a feedback hypothesis between energy consumption per capita and GDP per capita. A unidirectional causality flowing from electricity consumption to both GDP and Industry value added in the long-term was also detected. On the other hand, a study by Yuan, Kang, Zhao and Hu (2008) also validated a long-term association amongst electricity usage and economic growth in China. Similarly, a one-way causality moving from energy consumption to economic growth remained identified.

A study on the DRC conducted by Odhiambo (2014) indicates that, while both electricity consumption and economic growth Granger-cause each other in the short run; in the long run, it is economic growth that Granger-causes electricity consumption. This suggests that the DRC's long-term economic growth is not fully dependent on the electricity consumption; hence, the country could easily pursue electricity conservation measures without necessarily stifling its economic growth. This is according to the said research study.

Findings from a study by Yoo and Kwak (2010) on the relationship between electricity usage and economic growth vary from any country to another. A growth hypothesis was proven for Argentina, Brazil, Chile, Columbia and Ecuador. This suggests that in these countries, energy policies should focus on increasing electricity production (Khobai, 2017). For a country like Venezuela, a feedback hypothesis was found (Khobai, 2017). This means that any adjustment in electricity consumption has a direct impact on economic growth. Whereas for Peru, the results showed no causality between energy usage and economic growth.

According to a study by Chen et al. (2007) which focused on the 10 recently industrialised and developing Asian nations, similarly found that the results differ across the countries and range from unidirectional causality or bidirectional causality to no causality. Research from Narayan and Prasad (2008) established a unidirectional causality flowing from electricity consumption to economic growth in various countries such as Korea, the Czech Republic, Australia, Portugal, Italy, Iceland, UK and the Slovak Republic. A conservation hypothesis was also recognised for an additional 22 nations (Khobai, 2017).

Apergis and Payne's (2011) research study identified 88 countries, which were classified into different categories as follows: high, upper middle, lower middle and lower income countries. The panel Vector Error Correction Model (VECM) indicated that, for low-income countries, there is a unidirectional causality flowing from electricity consumption to economic growth for low income. It further recommended that for inferior middle income countries, a growth hypothesis was revealed in the short run while a feedback hypothesis was established in the long run. However, there was evidence of bidirectional causality flowing between electricity consumption and economic growth for high income and upper middle income countries (Khobai, 2017).

Moreover, Wen-Cheng Lu (2016) focused on 17 industries in Taiwan and the conclusions suggested that there was a long-run relationship between electricity consumption and economic growth. Results further suggested that a 1% increase in electricity consumption enhances economic growth by 1.72%. It was also established that economic growth and electricity consumption Granger-cause each other.

Cowan, Chang, Inglesi-Lotz and Gupta (2014) explored the causal relationship between energy usage, economic growth and carbon dioxide emissions for the Brics countries. The findings suggested a conservation hypothesis for South Africa and bidirectional causality between economic growth and electricity consumption for Russia. There remained however, causality established flowing between electricity consumption and economic growth in China, India and Brazil (Khobai, 2017).

It is thus found through the literature review process that the causal relationship between economic growth and energy consumption has been thoroughly investigated internationally with conflicting outcomes. Meanwhile, in South Africa, literature on this topic is very limited and tends to focus mainly on a symmetric co-integrating relationship, and has ignored the possibility of an asymmetric co-integrating relationship.

Furthermore, studies in South Africa have looked at the relationship between electricity consumption and economic growth using the ARDL (Auto-Regressive Distribution Lag) model (Asongu et al., 2016, Khobai et al., 2017). However, as previously indicated, in this study, the aim is to enhance the findings of previous studies by investigating the relationship between economic growth and electricity consumption in South Africa using the recent NARDL (Nonlinear Auto-Regressive Distribution Lag) model that takes into consideration nonlinear and asymmetric co-integration between variables.

Energy is a critical resource for modern life; it is considered as a backbone to production worldwide. The ever-increasing demand for it is principally due to rising standards of living, industrialisation and population growth. The causality between energy consumption and economic growth has attracted ample attention from economists and policy makers, in which countless studies have examined the relationship between these two. Unfortunately, findings from the various studies have been seemingly contradictory and different (Noh and Masih, 2017). Thus, formulation and implementation of policies for the conservation of energy need to be conducted with extreme care to avoid policies that may hamper development.

In addition, the numerous conflicting findings from various studies in literature suggest that the relationship between economic growth and electricity consumption depends on other variables that play a pivotal role.

It is clear from the literature review that, although numerous researcher have conducted studies on the relationship of economic growth and electricity consumption, the studies have primarily focused on the electricity consumption and economic growth link on a bivariate framework. Meanwhile, this approach has some limitations, particularly in respect of the omitted variable bias. This study fills in the gap by adding additional variables into the equation to form a multivariate framework. It is also observed from the various studies conducted that results are sensitive to countries of choice, sample period and methodology applied. Hence the need to use most recent data and sound methodology when understanding the asymmetric relationship of economic growth and electricity consumption in South Africa.

Most existing studies analyse the relationship between economic growth and electricity consumption symmetrically and claim an increase in one variable increases the other or vice versa. However, the relationship may be asymmetric. An increase in economic growth may reduce energy consumption due to technological innovation that may save energy requirements and/or Research and Development (R&D) as a consequence of economic growth (Bayat, Kayhan & Senturk, 2017). This would indicate a negative relationship between economic growth and electricity consumption. Hence the need to investigate the asymmetric relationship between variables as well as the direction of causation linkage.

Studies using a multivariate framework are very limited in South Africa. Nonetheless, findings from various studies portray an existence of a long-run causality flowing from trade openness, electricity prices, employment and capital to economic growth and electricity supply in several countries. Given that South Africa is largely electricity dependent, the performance of some factors of production like labour and capital will to some extent be possibly determined by sufficient supply of electricity. Also, by extrapolating from numerous studies conducted on several countries, free trade in South Africa may probably ensure that the country benefits from high technology input from other countries.

Finally, in most cases, existing studies on the causal relationship between economic growth and energy consumption have, to date, focused mainly on a symmetric co-integrating relationship, and have ignored the possibility of an asymmetric co-integrating relationship (Aworinde, 2015). This remains a major gap to be filled in the economic growth and energy consumption literature for South Africa. The kernel of this research is the use of a newly developed asymmetric causality test that separates the causal impact of positive shocks from negative shocks.

2.3 SUMMARY

This chapter reviewed current studies conducted globally, regionally and nationally on the relationship of economic growth and electricity consumption. Literature suggests that recent growing concerns on climate change have further prompted the interests of many researchers to examine the relationship between electricity consumption and growth in the economy. Results from case studies from numerous countries suggest that there is still persistent disagreement on the relationship between electricity and growth. This is largely attributed to the high level of sensitivity to countries of choice, sample period and methodology applied. In addition, the numerous conflicting findings from various studies in literature suggest that the relationship between economic growth and electricity consumption depends on other variables that play a pivotal role.

Taking into account the various literatures, the kernel of this research lies in its originality by investigating the asymmetric relationship between electricity consumption and growth through a multivariate framework including the following intermediary variables: trade openness, electricity prices, capital and employment.

The next chapter (Methodology) discusses specific procedures, techniques, or methods used for the selection, identification, processing and analysis of information with the view to achieve maximum validity and reliability.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter is dedicated to the research methodology which seek to provide clarity on the research strategy and how the data was collected. The various variables used in this research study are defined. The methodology approach for this study is also presented and the justification for the method selection is also given in this section. Furthermore, information on sampling and population is outlined and the specific sampling method is also clarified in this chapter. In addition, the technique used to analyse the secondary data collected and used to establish the relationship between the various variables is also detailed. Ethical consideration regarding the research, is also highlighted.

The most commonly used techniques for investigating the relationship between two or more quantitative variables are correlation and linear regression. Regression expresses the relationship in the form of an equation while correlation quantifies the strength of the linear relationship between a pair of variables. A correlation could be positive, meaning both variables move in the same direction. Alternatively, the relationship could be negative, meaning that when one variable's value increases, the other variable's values decreases. A causal relationship is when one variable causes a change in another. These types of relationships are investigated by experimental research in order to determine if changes in one variable actually result in changes in another variable.

The Nonlinear Auto-Regressive Distributed Lag Model (NARDL) is used in this study with the view to explore the extent of the relationship between electricity consumption and economic growth. In the literature, the relationship between these two variables is generally analysed under the assumption of a symmetric (linear) association. However, such an assumption is restrictive, due to many other variables that may have significant impacts on the relationship between the two variables of interest. It would therefore be more appropriate to use methods that allows for nonlinearity in modelling the relationship between the variables of interest.

3.2 VARIABLES

3.2.1 Energy consumption

Energy-intensive mining and manufacturing industries in South Africa account roughly for 60% of country’s electricity consumption but only 22% of GDP. Although there is a firm deterioration in the collective contribution of the manufacturing and mining sectors to GDP (from 31% of GDP in 1995 to 22% in 2015), these industries are still liable for approximately 60% of electricity consumption. As such, growth in these segments remains a significant determinant of the country’s overall demand. Meanwhile, the impact of the residential sector to entire South African electricity consumption has increased steadily over the past two decades (from 16% in 1993 to 23% in 2013). Findings from numerous local and international research studies on the key determinants of energy usage advise that GDP or income is seen as a dominant driver of demand. Moreover, further research suggests that demand in energy is generally more reactive to income than to price and that income over time is typically the dominant demand driver. An additional study tends to confirm this trend by revealing that activity/income is the leading driver of energy demand in the long-term, while the share of electricity in total energy demand and efficiency effects also play a secondary but still significant role. The varying structure of the economy remained to have the least impact (Deloitte, 2017).

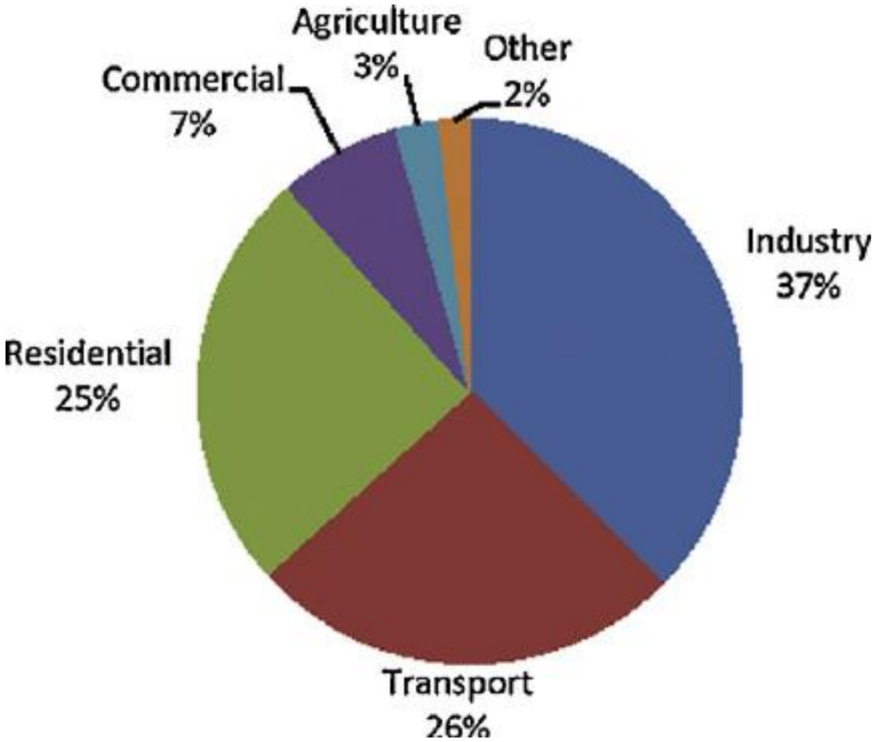


Figure 3.1: Energy distribution in South Africa (Deloitte, 2017)

3.2.2 Economic growth

Economic growth is plays a significant part in poverty alleviation and generating the resources necessary for both human development and environmental protection. Growth in the economy is believed to be influenced by many factors, including product, process and organisational innovations based on technological change. Economists regularly quantity economic growth with gross domestic product (GDP) or related indicators, such as gross national product (GNP) or gross national income (GNI) which is derived from the GDP calculation. A country's national accounts which reports annual data on income, expenditure and investments for each sector of the economy forms the basis in which GDP is calculated. The extract below describes the current situation at Eskom, according to the Department of the Treasury.

> *"South Africa's GDP growth forecast for 2019 has been revised to 1.5 per cent, from an estimated 1.7 per cent at the time of the 2018 MTBPS. The weaker outlook projects a slow improvement in production and employment following poor investment growth in 2018, and a moderation in global trade and investment. The medium-term outlook is subdued, with GDP growth projected to reach 2.1 per cent in 2021, supported by a gradual improvement in*

confidence, more effective public infrastructure spending, and a better commodity price outlook than previously assumed. Following a decade of economic weakness, there are positive signs that the economy has begun to gain lost ground. The policy inertia and uncertainty that have constrained investment and confidence have begun to lift. The reconfiguration of Eskom is a major step in the broad reform of state-owned companies. Several commissions are probing allegations of widespread corruption in the public and private sectors. The President's investment drive has yielded pledges of R300 billion in investment. Economic growth expected to rise slowly from 1.5 per cent in S 2019 to 2.1 per cent in 2021. Separating Eskom is major step in broad reform of state-owned companies. Over the next three years, general government infrastructure investment is projected at R526 billion. Interventions are already under way to improve the efficiency of this pipeline. In addition, government will contribute R100 billion to a blended-finance infrastructure fund over the next decade in the form of new spending, reprioritisation and guarantees. The fund will allow the public and private sectors to work together to finance sustainable social and economic infrastructure projects. Government is acting decisively to mitigate the risks that Eskom poses to the economy and the public finances. The restructuring of the electricity sector and state support for Eskom's balance sheet are central to a transparent and credible reform of the utility's business model. Over the long term, this will support the transition to a more sustainable and resilient economy. The President's economic stimulus and recovery plan, announced in September 2018, aims to restore policy certainty and boost confidence in the near term. Efforts to implement the growth-enhancing reforms outlined in the plan have made some headway".

(www.treasury.gov.za)

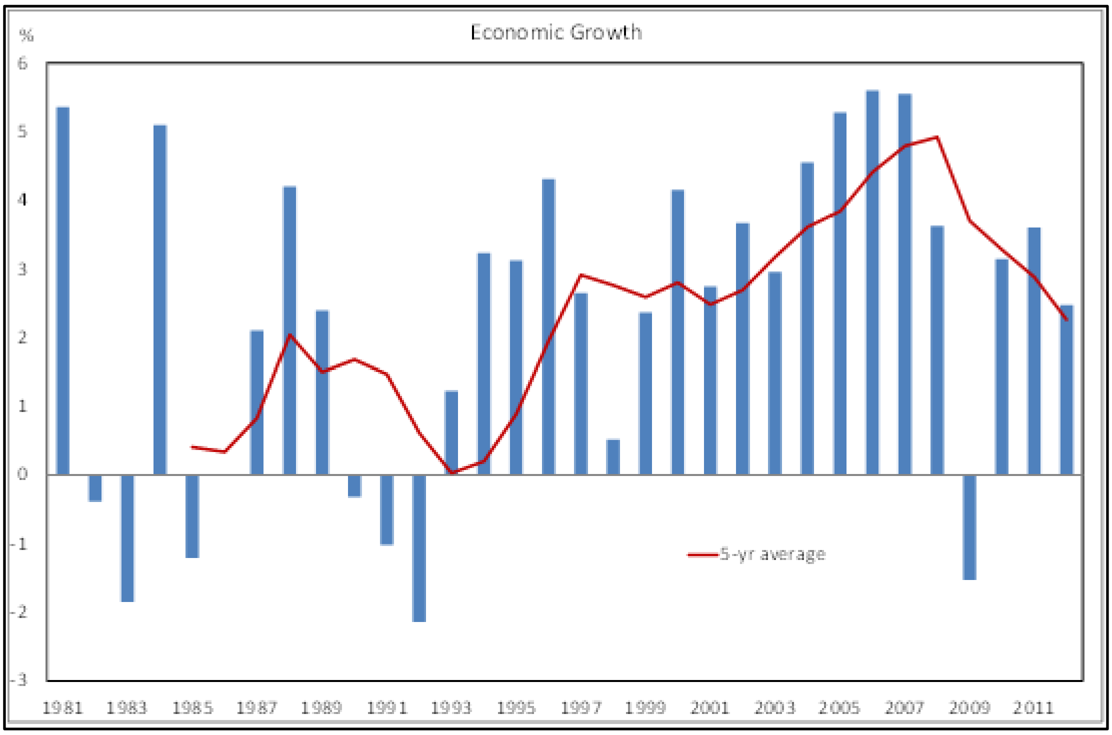


Figure 3.2: South Africa Economic Growth (Deloitte, 2017)

3.2.3 Electricity price

Although there was a time where real electricity tariffs were sharply rising, for much of the past four decades, real (inflation-adjusted) price of electricity in South Africa was declining. Prices of electricity steadily fell after a substantial over-investment in electricity generation capability in the late 1970s and early 1980s. During year 2004/2005 average electricity prices in South Africa remained amongst the lowest in internationally. In 2008, after Eskom introduced load shedding as a result of the challenges it faced in meeting the demand, trends in prices took a dramatic turn. Subsequently, with the massive infrastructure built programme initiated by Eskom to increase the generation capacity, NERSA approved several sharp increases in annual tariffs. This resulted in electricity prices more than doubled in real terms (inflation-adjusted) rising by a cumulative 114% between 2008 and 2013.

Meanwhile, a study by Deloitte (2017) reveals that the sensitivity of consumers to adjustments in electricity prices seems to differ significantly over time. This is also dependent on the prevailing price level and the direction and magnitude of price increases. It is also evident from the literature that though the income elasticity of electricity demand is positive and relatively unchanging over time there are likely to be enormous differences in the sensitivity of consumers to price. In addition, it also appears that prevailing conditions in a nation's electricity market and geographical locations has an effect on the sensitivity of consumers to tariff fluctuations. Our analysis of South African GDP and electricity sales growth data in the 20 years to 2016 offers evidence of a very strong positive correlation between GDP and electricity usage in South Africa - the correlation coefficient between the two series over this period is 0.93. Inglesi-Lotz (2011) conducted a study in South Africa and found that, from 1986 to 2005, income was the dominant driver of demand and that the income elasticity of demand was close to 1 (unit elastic) for most of the period beyond 1990, meaning that a 1% increase in GDP was related with a 1% increase in electricity demand.

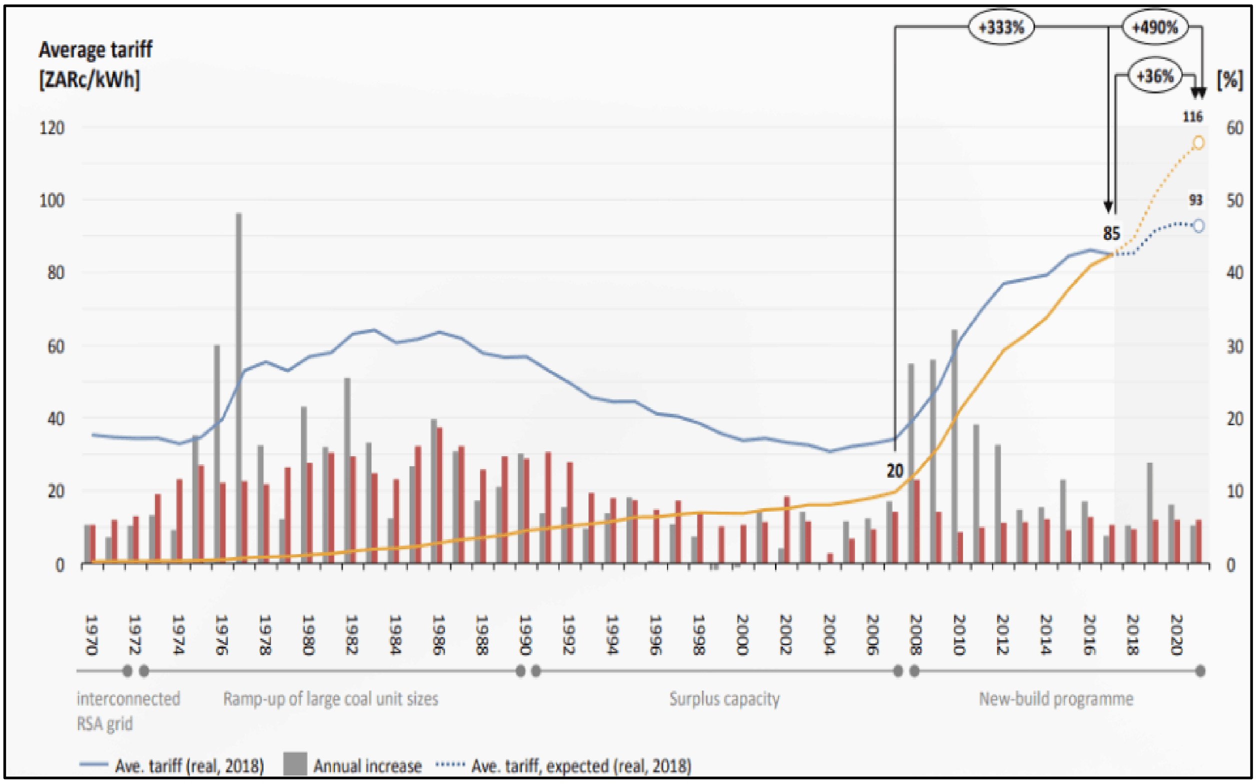


Figure 3.3: Evolution of Electricity prices in South Africa (https://www.thesouthafrican.com/news/eskom-electricity-prices-for-april-from-1970/)

3.2.4 Trade openness

Trade openness affects energy demand through various effects such as scale, technique and composite. In an ideal situation, trade openness increases economic activities, consequently stimulates domestic production and therefore economic growth. Scale effect is referred to as the change in energy demand resulting from expansion in domestic production. Such a scale effect is caused by trade openness. The impact of trade openness on energy usage is determined by the economic condition of the country and the extent of the relationship between economic growth and trade openness (Shahbaz, Jalil & Islam 2013). Trade openness facilitates the import of advanced technologies from one country to another and, subsequently, the adoption of advanced technologies lowers energy intensity. The technique effect refers to the economic consequences of advance technology implementations that consume less energy and produce more output. Meanwhile, composite effect refers to the use of energy intensive production attributed to the shift from traditional means of production to industrialisation. Following the maturity stage of economic development, shifts in the industry consume less energy which implies that energy intensity is lowered because of the composite effect.

Energy affects trade openness via various channels. Originally, machinery and equipment in the process of production require energy; hence energy is an important input of production. Then, exporting or importing manufactured goods or raw material requires energy to fuel transportation. Without an adequate energy supply, trade openness will be adversely affected. Consequently, trade expansion depends on energy and adequate consumption of energy is essential to expand trade via expanding exports and imports. The relationship between trade openness and energy consumption is therefore critical. As flows of exports or imports are energy dependent, any energy conservation policies will have a negative impact on the flow of exports or imports. This is the reason for reducing the benefit of trade openness. The bidirectional causal relationship between trade openness and electricity usage recommends adopting energy expansion policies because energy usage encourages trade openness and as result, trade openness affects energy consumption (Sadorsky, 2011). The energy conservation policies will not have an adverse effect on trade openness if causality is running from trade openness to energy consumption or a neutral effect exists between trade openness and energy consumption (Sadorsky, 2011). Energy consumption in the world increases parallel to technological development, increases in trade and population growth. The world average energy consumption was 1454 Kg of oil equivalent per capita in 1980 while the amount increased to 1852 Kg of oil equivalent per capita in 2010. According to the American

Energy Information Administration (EIA) and the International Energy Agency (IEA), the worldwide energy consumption will on average continue to increase by 2% per year (www.iea.org) Figure 3.3 below depicts South Africa's trade openness.

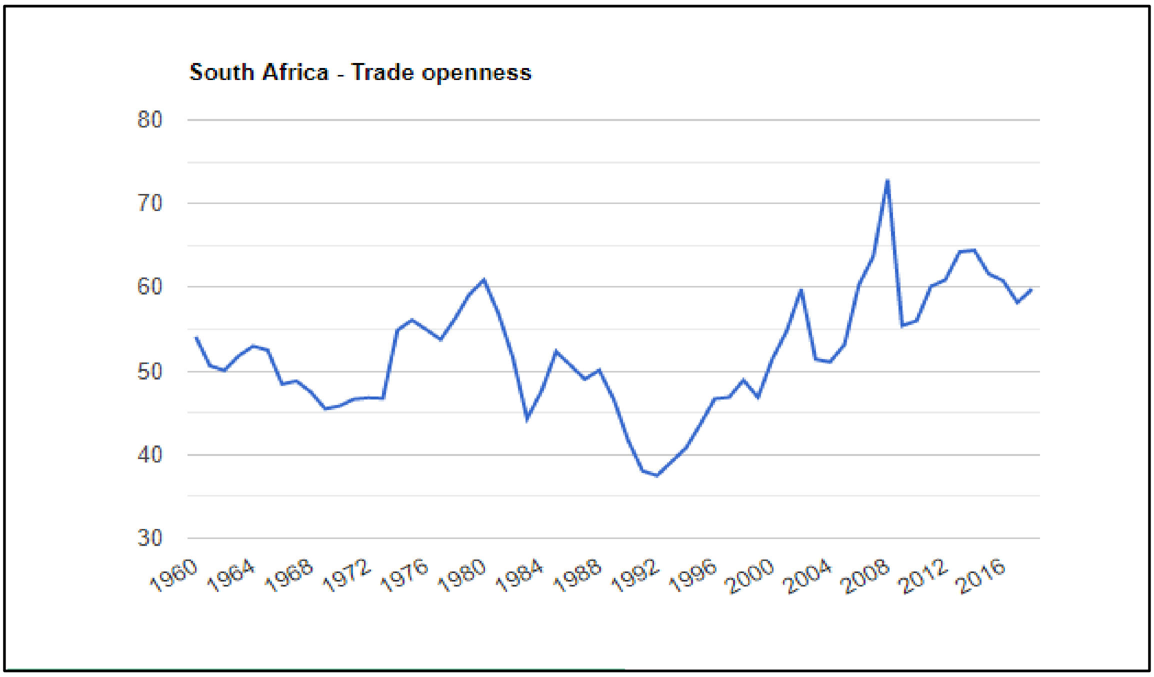


Figure 3.4: South Africa Trade Openness (https://www.theglobaleconomy.com/South-Africa/trade_openness/)

3.2.5 Capital

Although it is still considered as an important factor of economic growth, capital formation was once seen as a crucial element in the development of underdeveloped economies but recent trends are now running against this view. In the context of economic growth, the importance of capital formation is now overtaken by factors such as supply chain, entrepreneurship, widening of markets, and technological progress. Hence, leading textbooks on economic development are now sceptical about the central role of capital accumulation. There is clearly disagreement in the literature between those who emphasise capital and those who view it more modestly. Nevertheless, it is generally agreed that large amounts of capital are necessary in underdeveloped economies for capital deepening and widening. Backward methods are replaced by known capital-intensive production methods for broader economic development. Figure 3.5 suggests a close correlation between GDP and Capital formation in South Africa from 2011 to 2017.

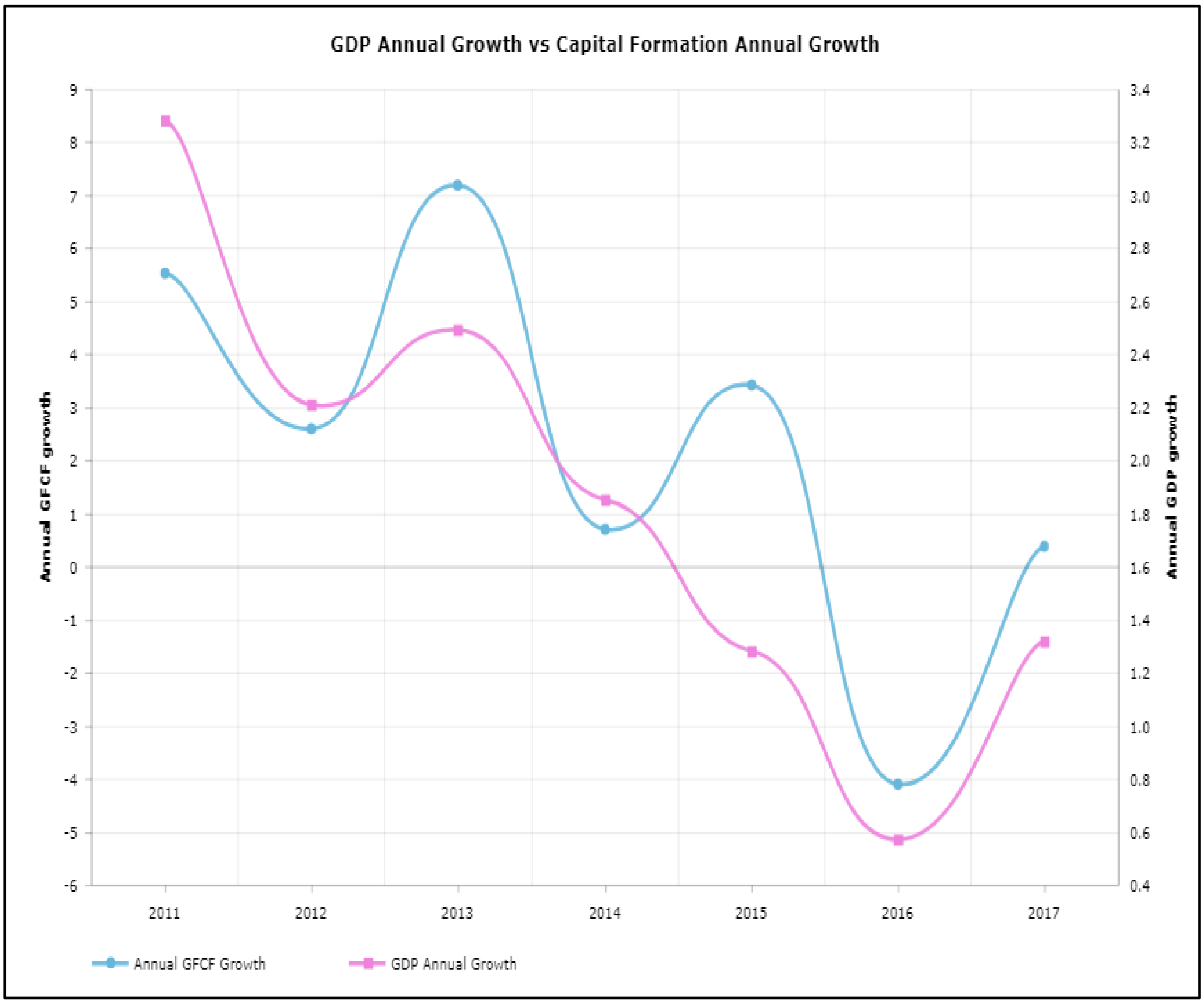


Figure 3.5: GDP annual growth VS Capital formation annual growth (South African Market insights, 2018)

3.2.6 Labour (Human capital)

The current unemployment rate for South Africa, which includes the discouraged work seekers, is approximately 30%. The South African administration has placed several structures and plans in place to meet the challenge of job creation. These policies and structures include the Accelerated and Shared Growth Initiative of South Africa (ASGISA), Growth, Employment and Redistribution strategy (GEAR), SMME development institutions, Special Development Initiatives (SDI), the National Skills Fund, the Umsobomvu Youth Agency, the Sector Education and Training Authorities (SETAs) and the National Empowerment Fund. Although there are all these initiatives, contemporary growth and unemployment rates in South Africa are a development concern, Other associated issues which include aggregate demand, inflation, interest rates, budget deficits and increasing income inequalities are also of great worry for the country. The projections for sustained and rapid growth, without which poverty cannot be addressed, are themselves impacted negatively by increasing inequality, poverty and unemployment (Bhorat & Kanbur, 2005).

Increasingly, as unemployment between the poorer community remains tremendously high, signs of disappointment among individuals are persistently visible. The HIV/AIDs epidemic remains extremely high, crime rates are disturbing, corruption is a major issue and subject of topic, service delivery remains a serious challenge, while disgruntled workers in several sectors are increasingly expressing their disillusionment with salary or working conditions (Mahadea and Simson, 2010). But then again what is evident is that regulation does not create employment. The higher the degree of regulation in a country, the higher the rate of unemployment rate tends to be. Greater flexibility in the labour market is a least requirement for the creation of employment. It is entrepreneurial action that gives rise to growth and employment.

Meanwhile, given its crucial role in production of goods and services, human capital (labour) is intimately related to growth. It creates job opportunities and lifts the standard of living through increases in income levels. Economic growth refers to the increase in the amount of goods and services produced over times. Yet production of goods and services are linked to productivity, which depends to a large extent to the quality of labour, whether it is skilled or not.

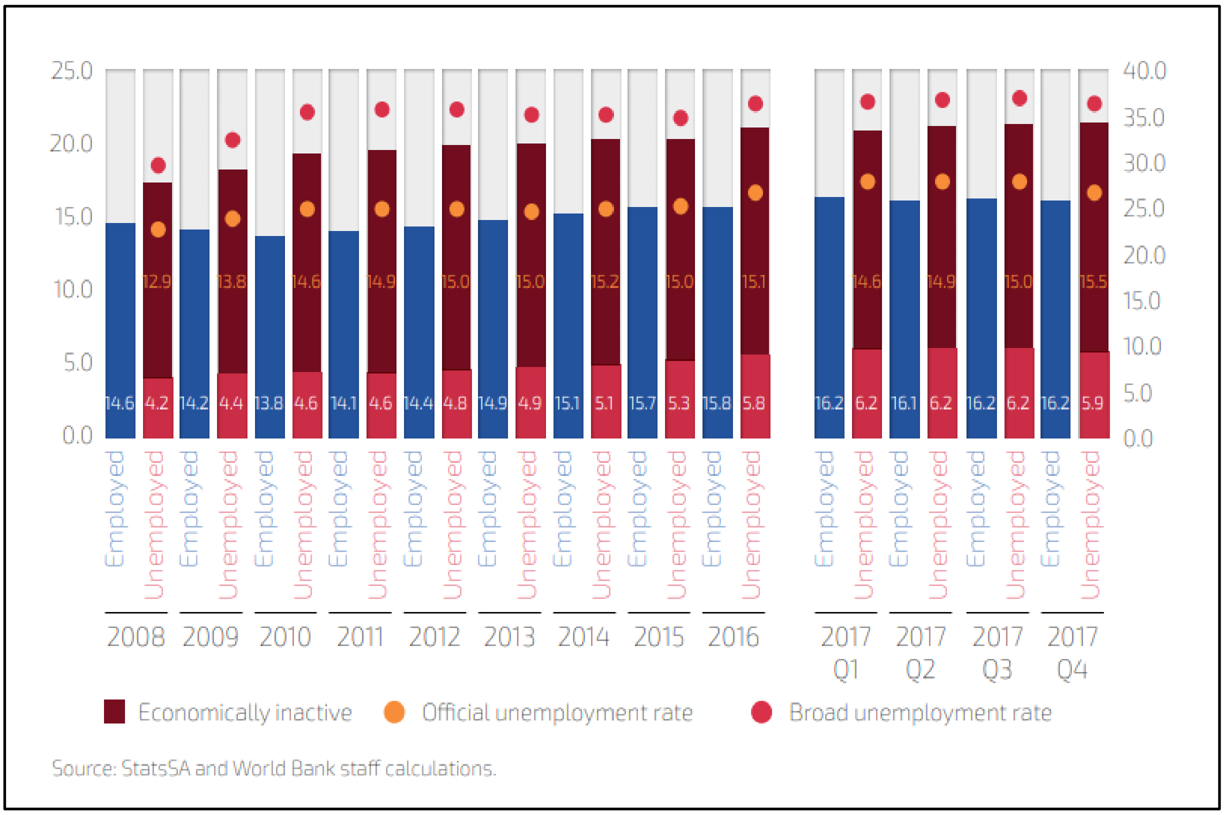


Figure 3.6: Labour market developments in South Africa (National Treasury, 2018)

3.3 METHODOLOGY APPROACH

Recently, in the context of investigating relationships between variables, there is an increasing number of powerful programming tools to assist with data wrangling and analysis in order to fit many models and understand how they work. Figure 3.7 below depicts the methodology approach for this study.

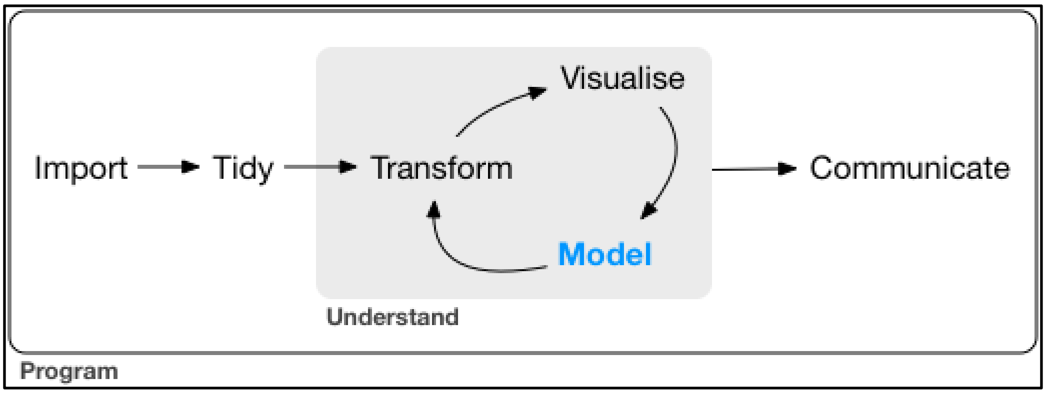


Figure 3.7: Methodology process (Grolemund and Wickham, 2017)

The goal of a model is to provide a simple low-dimensional summary of a dataset and the methodology process. Ideally, the model will assist in splitting true “signals” (patterns generated by the phenomenon of interest) from “noise” (random variations that are irrelevant). In this context, the model is used not for prediction but rather for “data relationships discovery” purposes.

- Import:

To increase the reliability of this study, data from the various variables are imported from the same source, World Development Indicators.

- Data Tidying:

> *“Tidy datasets are all alike but every messy dataset is messy in its own way”* (Grolemund and Wickham, 2017).

Data scientists use computers to store, transform, visualise, and model their data. As a result, for every data science project, it starts with preparing data using a computer. Depending on the uniqueness of each computer programme, data sets needs to be organised in a predetermined way to fit the requirements of the programme. Such a process of organising data is referred to as “tidying”. In this study, R programming is an excellent language for data science because the software, which is freely accessible online, allows for data importing, transformation, visualisation, exploration, modelling and testing.

There are numerous ways for organising data. Some of these ways can make for easy data analysis while others could lead to frustration. This emphasises the criticality of this process. In the framework of tidying data every row is an observation, every column represents variables and every entry into the cells of the data frame is a value. R programming for Data Science sums this up with the following graphic:

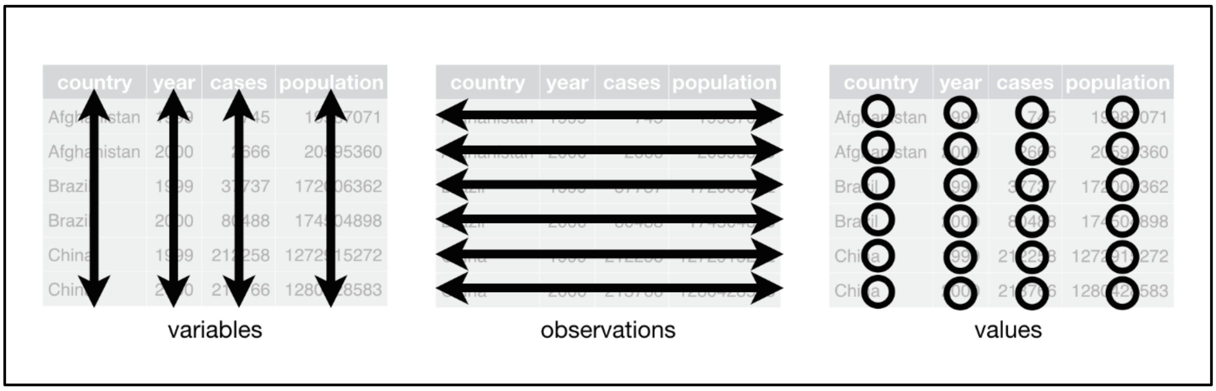


Figure 3.8: Data Tidying

- Transformation:

Most parametric tests require that residuals be normally distributed and that the residuals be homoscedastic. One approach when residuals fail to meet these conditions is to transform one or more variables to better follow a normal distribution. Often, just the dependent variable in a model will need to be transformed. However, in complex models and multiple regression, it is sometimes helpful to transform both dependent and independent variables that deviate greatly from a normal distribution. Transformations are useful to approximate non-linear functions. This entails using a polynomial function to get arbitrarily close to a smooth function by fitting an equation. Conducting such an exercise by hand is tedious, so R programming provides an automatic solution for this. Missing values cannot convey any information about the relationship between the variables, so modelling functions will drop any rows that contain missing values. R's default behaviour is to silently drop them. In this study, growth will be used for transformation of data.

- Model:

A statistical model defines a mathematical relationship between the two variables of interest in this case. The model is a representation of the real Y that aims to replace it as far as possible. At least the model should capture the dependence of Y on the Xi s. The response variable is the one whose content we are trying to model with other variables, called the explanatory variables. In any given model there is one response variable (Y above) and there may be many explanatory variables (like X1, ...Xn). In the first process, energy consumption is considered as the response variable. Thereafter, the process is reversed with economic growth as the response variable.

- Communicate:

The coefficient of determination is a measure used in statistical analysis that assesses how well a model clarifies and foresees future outcomes. It is indicative of the level of explained variability in the data set. The coefficient of determination, also usually known as "R-squared," is used as a guideline to measure the accuracy of the model. One way of interpreting this figure is to say that the variables included in a given model explain approximately x% of the observed variation. So, if the $R^2 = 0.50$, then about half of the observed variation can be clarified by the model. The coefficient of determination is used to explain how much variability of single factor can be caused by its correlation to an additional factor. It is relied on heavily in trend analysis and is represented as a value between 0 and 1. The closer the value is to 1, the better the fit, or relationship, between the two factors.

The coefficient of determination is the square of the correlation between the predicted scores in a data set versus the actual set of scores. It can also be expressed as the square of the correlation between X and Y scores, with the X being the independent variable and the Y being the dependent variable. Regardless of representation, an R-squared equal to 0 means that the dependent variable cannot be predicted using the independent variable. Conversely, if it equals 1, it means that the dependency of a variable is always predicted by the independent variable. A coefficient of determination that falls within this range measures the extent that the dependent variable is predicted by the independent variable. An R-squared of 0.20, for example, means that 20% of the dependent variable is predicted by the independent variable.

The goodness of fit, or the degree of linear correlation, measures the distance between a fitted line on a graph and all the data points that are scattered around the graph. The tight set of data will have a regression line that is very close to the points and have a high level of fit, meaning that the distance between the line and the data is very small. A good fit has an R-squared that is close to 1.

However, R-squared is unable to determine whether the data points or predictions are biased. It also does not tell the analyst or user whether the coefficient of determination value is good or not. A low R-squared is not bad, for example, and it is up to the person to make a decision based on the R-squared number.

The coefficient of determination should not be interpreted naively. For example, if a model's R-squared is reported at 75%, the variance of its errors is 75% less than the variance of the dependent variable, and the standard deviation of its errors is 50% less than the standard deviation of the dependent variable. The standard deviation of the model's errors is about one-third the size of the standard deviation of the errors that you would get with a constant-only model.

Finally, even if an R-squared value is large, there may be no statistical significance of the explanatory variables in a model, or the effective size of these variables may be very small in practical terms. Hence the need to read it in combination with the p value as it is done in this case study.

3.4 SAMPLING AND POPULATION

In this research study, the asymmetric relationship between economic growth and electricity consumption is examined. The sample population that is considered for this study is annual data for the period 1980 to 2013. The reason why the study has considered the period from 1980 to 2013 is because the chosen period covers the apartheid era (1980 to 1994) when South Africa faced trade sanctions and low economic growth which led to capital outflows from the country. Furthermore, on the electricity side, South Africa experienced low levels of electricity access which was mostly from the exclusion of low income and poor households. The study period 1980 to 2013 will also cover post-apartheid years (1994 to 2013), when South Africa developed developmental policies to accelerate economic growth and catered for low income and poor household. The exact selection period is based on the latest publicly available data from the secondary source, the World Bank.

3.5 ETHICAL CONSIDERATION

In this research study, all ethical procedures have been followed. The study used publicly available secondary data to run econometric models. We did not collect primary data through direct interaction with, or data gathering from human participates as individuals, members of a group, organisation or institution. We have collected publicly available secondary data from reputable sources such as the World Bank.

3.6 WHAT IS R PROGRAMMING?

R programming is used in this study to analyse data and establish relationships between the various variables.

> *"R is a language and environment for statistical computing and graphics. It is a GNU project which is similar to the S language and environment which was developed at Bell Laboratories (formerly AT&T, now Lucent Technologies) by John Chambers and colleagues. R can be considered as a different implementation of S. There are some important differences, but much code written for S runs unaltered under R.*
>
> *R provides a wide variety of statistical (linear and nonlinear modelling, classical statistical tests, time-series analysis, classification, clustering …) and graphical techniques, and is highly extensible. The S language is often the vehicle of choice for research in statistical methodology, and R provides an Open Source route to participation in that activity.*
>
> *One of R's strengths is the ease with which well-designed publication-quality plots can be produced, including mathematical symbols and formulae where needed. Great care has been taken over the defaults for the minor design choices in graphics, but the user retains full control.*
>
> *R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License in source code form. It compiles and runs on a wide variety of UNIX platforms and similar systems (including FreeBSD and Linux), Windows and MacOS.*
>
> *R is an integrated suite of software facilities for data manipulation, calculation and graphical display. It includes*
>
> - *an effective data handling and storage facility,*

- *a suite of operators for calculations on arrays, in particular matrices,*
- *a large, coherent, integrated collection of intermediate tools for data analysis,*
- *graphical facilities for data analysis and display either on-screen or on hardcopy, and*
- *a well-developed, simple and effective programming language which includes conditionals, loops, user-defined recursive functions and input and output facilities.*

The term "environment" is intended to characterise it as a fully planned and coherent system, rather than an incremental accretion of very specific and inflexible tools, as is frequently the case with other data analysis software.

R, like S, is designed around a true computer language, and it allows users to add additional functionality by defining new functions. Much of the system is itself written in the R dialect of S, which makes it easy for users to follow the algorithmic choices made. For computationally-intensive tasks, C, C++ and Fortran code can be linked and called at run time. Advanced users can write C code to manipulate R objects directly.

Many users think of R as a statistics system. We prefer to think of it as an environment within which statistical techniques are implemented. R can be extended (easily) via packages. There are about eight packages supplied with the R distribution and many more are available through the CRAN family of Internet sites covering a very wide range of modern statistics.

R has its own LaTeX-like documentation format, which is used to supply comprehensive documentation, both on-line in a number of formats and in hardcopy".

(https://www.r-project.org/about.html)

3.7 SUMMARY

This chapter started by contextualising and defining all variables under in this research study. These variables are energy consumption, economic growth, electricity prices, trade openness, capital and labour.

A methodology process was then explained using a model from Grolemund and Wickham (2017). The model consists of providing a simple low-dimensional summary of dataset and methodology process through import, data tidying, transformation, statistical modelling, and communication. Thereafter, the chapter focussed on the approach used for sampling, population identification as well as ethical considerations. Finally, R programming was introduced to explain why it was the preferred tool for this research study and what it could possibly achieve. In brief, the chapter demonstrated methodically the rationality of using R programming in conducting this research study. Subsequently, in Chapter 4, data is used and processed with R programming. At the end of chapter 4, a conclusion is drawn based on findings generated from R programming.

CHAPTER 4

DATA, EMPIRICAL ANAYSIS AND FINDINGS

4.1 INTRODUCTION

Chapter 3 discussed the research methodology process. In this chapter the application of the methodology using R programming on the data collected is presented and discussed. Most of the ground works are done behind the R programming software and the chapter discusses the outputs of the data collected from the software following data inputs made as explained in chapter 3. The secondary data collected is used to inform the findings of this research study.

4.2 RAW DATA

In an effort to achieve maximum reliability of research results, this research should ideally cover a greater span period of study. However, records on the history of electricity prices and labour histograms are very limited and inconsistent; and they largely vary from one source to another. The most reliable record from World Development indicators reflects data from 1980 to 2014 for electricity prices. There was therefore a need to select between a reduced span of study from 1989 to 2014 or an increase in time span by omitting the electricity prices from the study. After careful evaluation, the best option selected for achieving reliability of results is to exclude the electricity prices and labour from this study. The span period of the study is therefore extended from 1980 to 2014.

Table 4.1: Raw Data (World Development indicators)

SOUTH AFRICA					
t	Trade(%ofGDP)	Gross Capital Formation (%ofGDP)	Energy Consumption (kWhpercapita)	GDP per Capita (US$)	GDP growth (annual%)
1980	60,88692208	31,35637804	3519,270685	2905,807845	6,620585081
1981	56,88797621	34,11518408	3678,88116	2913,241756	5,360737419
1982	51,63881484	26,52871889	3750,226199	2601,057861	-0,383390769
1983	44,30331656	27,17322107	3789,537235	2820,434082	-1,846544477
1984	47,61533338	25,54336395	4034,974004	2429,027119	5,09911491
1985	52,31173486	22,04957623	4117,797939	1807,976578	-1,211483719
1986	50,67892073	21,02094122	4205,702104	2015,813748	0,017834778
1987	49,01380178	17,78428404	4175,116328	2582,494671	2,100735221
1988	50,09081204	21,22829638	4255,160458	2711,514991	4,200132549
1989	46,59102285	22,74589375	4271,327204	2756,212608	2,394784159
1990	41,68263812	19,41325413	4238,74572	3139,966054	-0,317785676
1991	38,05081155	19,02496749	4128,269742	3285,95465	-1,018219873
1992	37,4874584	16,76860652	3997,04111	3479,066283	-2,137056889
1993	39,12332188	15,1623208	4023,288233	3388,729303	1,233519913
1994	40,76895329	17,72010326	4068,478453	3445,230068	3,200001049
1995	43,61093869	19,16665189	4157,568446	3751,854328	3,099995418
1996	46,66732849	18,04002767	4705,947971	3494,383567	4,299998961
1997	46,84526188	17,71511711	4818,49812	3549,579815	2,600002116
1998	48,89661764	17,99153951	4606,904496	3154,020777	0,500000905
1999	46,86188609	17,03509901	4470,963333	3081,569927	2,399996245
2000	51,43777395	16,3653252	4579,953241	3032,427138	4,200003476
2001	54,80163343	15,74458201	4302,11804	2666,480846	2,699994567
2002	59,7646363	16,27796741	4528,816147	2502,265926	3,700382352
2003	51,40183109	17,10588445	4559,77453	3751,258432	2,949079137
2004	51,07803414	18,46659574	4589,905059	4833,633129	4,554552745
2005	53,14911539	18,31497742	4636,9301	5383,632556	5,277056312
2006	60,27726433	20,18299445	4721,933482	5601,970369	5,603797657
2007	63,68308729	20,9855217	4851,693185	6095,652721	5,360475891
2008	72,86539024	23,15016528	4665,176133	5760,789016	3,191046741
2009	55,4182616	20,70489939	4428,154433	5862,81522	-1,538089334
2010	55,98898581	19,51298134	4542,596473	7328,593646	3,039730814
2011	60,1126299	19,72094808	4566,287489	8007,377412	3,284168142
2012	60,89969944	19,96598504	4365,91926	7501,40728	2,213354808
2013	64,24175982	21,16355695	4285,47726	6829,020465	2,4852005
2014	64,43450111	20,49949351	4197,907047	6428,293579	1,846991604

4.3 RAW DATA TRENDS ON R PROGRAMMING

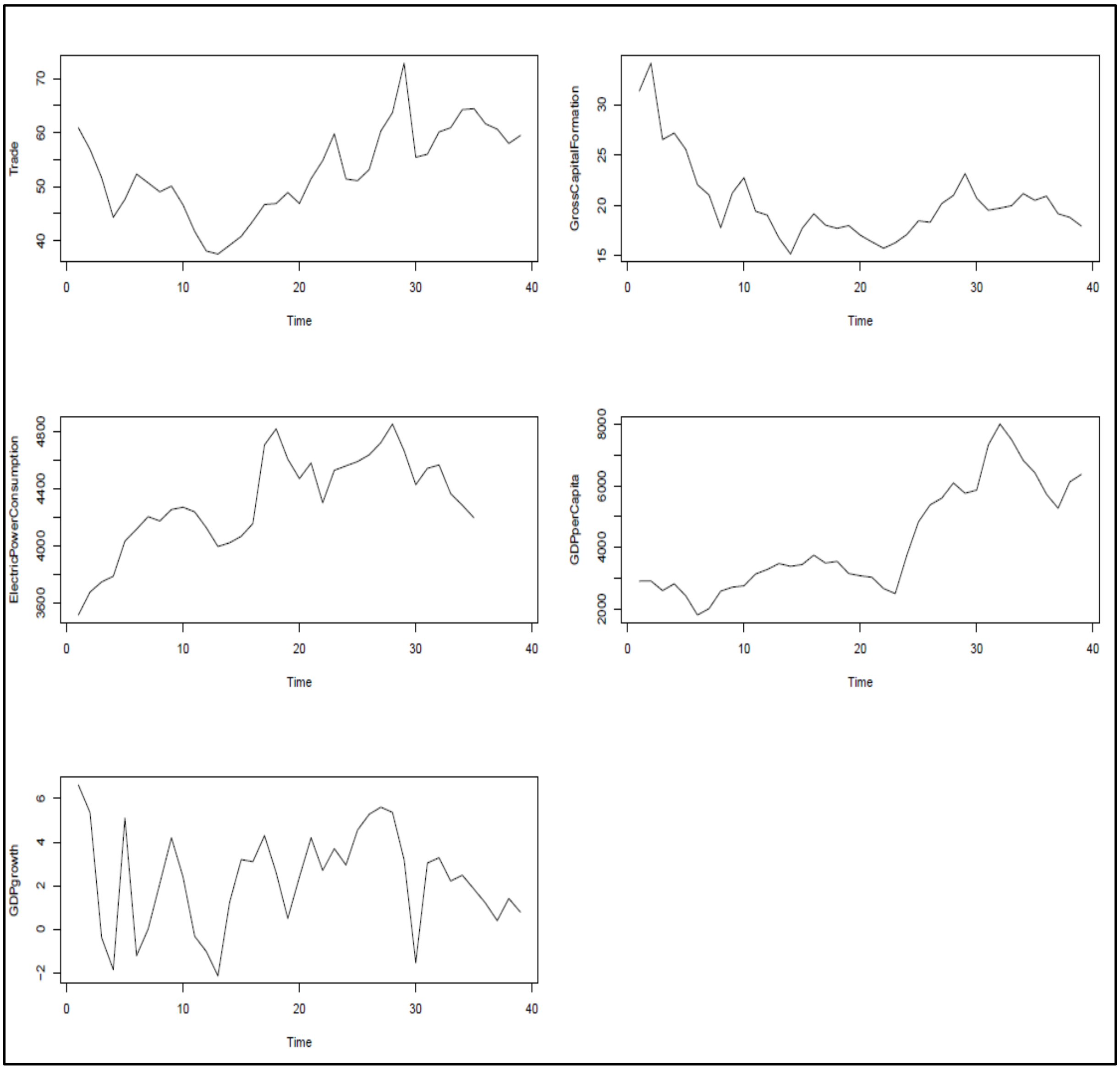


Figure 4.1: Raw data trends on R programming

The first tendency from our raw data base indicated that, from the 5 variables, only GDP growth seems to follow a stationary evolution (oscillation around a mean value). Modelling a time series based on another takes on a dynamic character. It should be taken into account that the current values of a variable may influence its future values (self-regression) but that future values may depend on external factors.

4.4 TRANSFORMED DATA

Since the variables of interest are dynamic, it is worth preparing the data. The goal is to describe one variable based on another. This requires that the variables of interest stationarise in order to remove the volatile character.

In order to achieve maximum reliability, four variables are created as follows: energy consumption growth, trade growth, GDP per capita growth and gross capital formation growth:

$$\boldsymbol{XGrowth_t} = {}^{(\boldsymbol{X_t} - \boldsymbol{X_{t-1}})}/_{\boldsymbol{X_{t-1}}}$$

This transformation is important as it allows the study to diminish the volatile nature of the variables prior to the determination of the different existing relationships.

Table 4.2: Transformed growth data

SOUTH AFRICA					
t	GDP growth (annual%)	Energy Consumption Growth	Trade Growth	GDP per capita Growth	Gross Capital Formation Growth
1980	6,620585081				
1981	5,360737419	4,535328186	-6,567823975	0,255829418	8,79822931
1982	-0,383390769	1,939313491	-9,227189507	-10,71603119	-22,23779643
1983	-1,846544477	1,048231071	-14,20539627	8,434115349	2,429450809
1984	5,09911491	6,476695003	7,475776251	-13,87754336	-5,998026944
1985	-1,211483719	2,052651015	9,863212438	-25,56787183	-13,67786844
1986	0,017834778	2,134737213	-3,121315211	11,49556757	-4,665101048
1987	2,100735221	-0,727245424	-3,285624316	28,11176997	-15,39729903
1988	4,200132549	1,917171249	2,197361184	4,995956871	19,36548209
1989	2,394784159	0,379932707	-6,986888513	1,648437014	7,1489362
1990	-0,317785676	-0,762795327	-10,53504395	13,9232164	-14,6516099
1991	-1,018219873	-2,606336507	-8,713043911	4,649368612	-2,000111015
1992	-2,137056889	-3,178780478	-1,480528612	5,876880647	-11,8599991
1993	1,233519913	0,656663827	4,363762039	-2,596586925	-9,579124678
1994	3,200001049	1,123216069	4,206267093	1,667314206	16,86933351
1995	3,099995418	2,189761954	6,970955023	8,899964705	8,163319417
1996	4,299998961	13,18990972	7,008310047	-6,862493557	-5,878043927
1997	2,600002116	2,391657316	0,381280438	1,579570402	-1,801053536
1998	0,500000905	-4,391277494	4,379003715	-11,14382713	1,560375773
1999	2,399996245	-2,95081357	-4,161293049	-2,297094883	-5,31605705
2000	4,200003476	2,437727617	9,764625895	-1,594732221	-3,93172831
2001	2,699994567	-6,066332691	6,539667668	-12,06776866	-3,793039124
2002	3,700382352	5,269453432	9,056304635	-6,158488638	3,387739366
2003	2,949079137	0,683586664	-13,99289901	49,91445922	5,086120495
2004	4,554552745	0,660789886	-0,629932727	28,85364249	7,954638628
2005	5,277056312	1,024531891	4,054739556	11,37859272	-0,821040968
2006	5,603797657	1,833182306	13,41160409	4,05558534	10,19939577
2007	5,360475891	2,748020556	5,650261339	8,812655536	3,976254606
2008	3,191046741	-3,844370317	14,41874655	-5,493483961	10,31493811
2009	-1,538089334	-5,080659193	-23,94432882	1,771045654	-10,56262818
2010	3,039730814	2,584418447	1,029848627	25,00127278	-5,756695723
2011	3,284168142	0,521530297	7,365098752	9,262128571	1,065786595
2012	2,213354808	-4,387989808	1,309324734	-6,3187996	1,242521234
2013	2,4852005	-1,84249856	5,487810966	-8,963475643	5,998060701
2014	1,846991604	-2,043417992	0,300024929	-5,8679995	-3,137768578

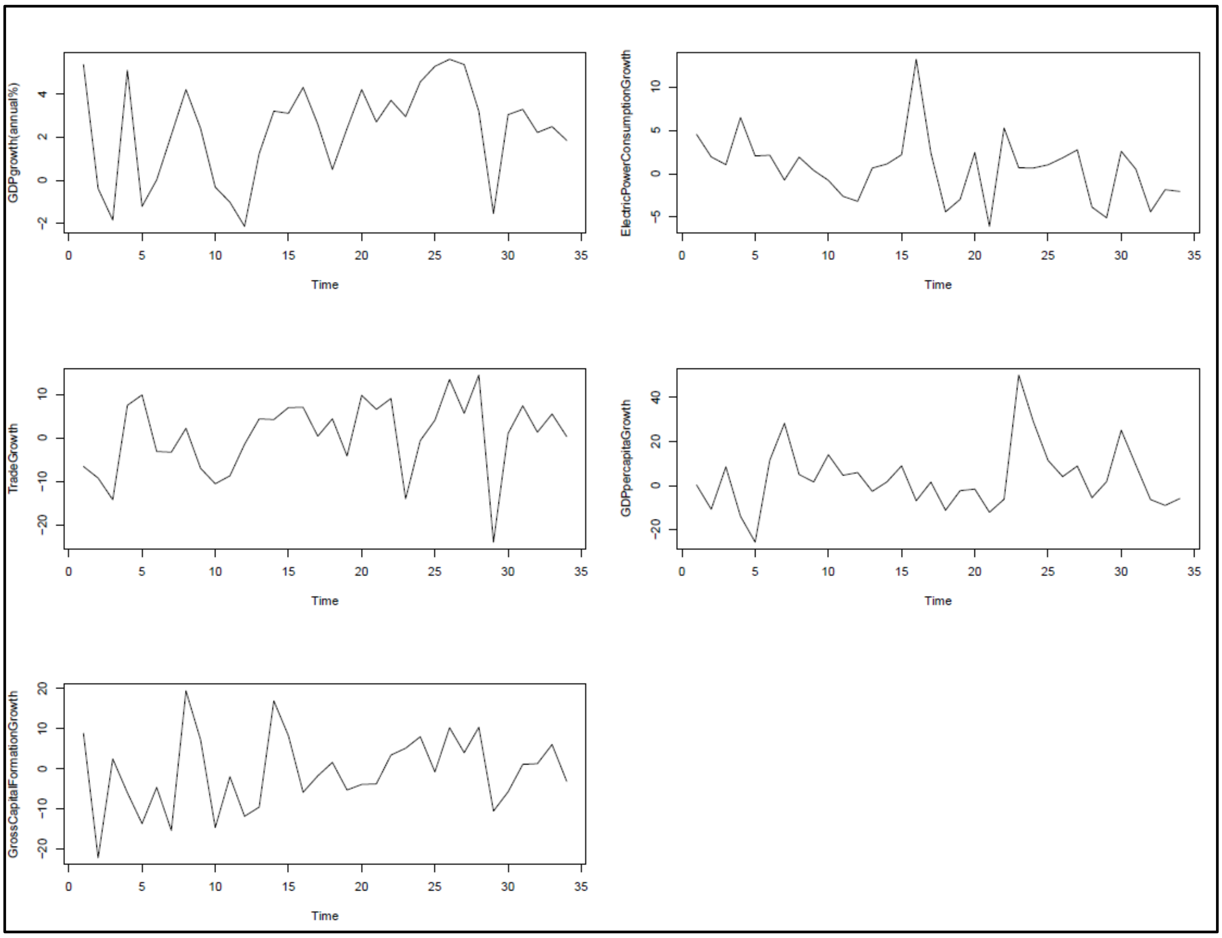


Figure 4.2: Trends on transformed variables

It is clear from the look of figure 4.2, that the process appears stationary and this is further demonstrated mathematically below with the Phillips-Perron test.

- ✓ ***Phillips-Perron Test:***

Phillips-Perron tests assess the null hypothesis of a unit root in a univariate time series *y*. All tests use the model:

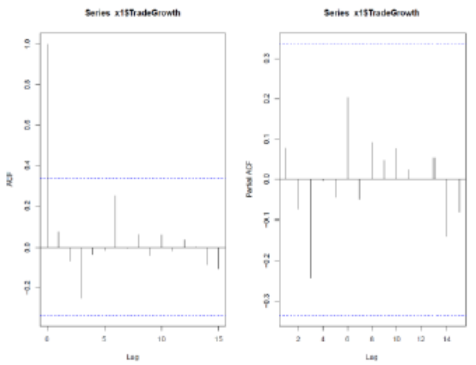
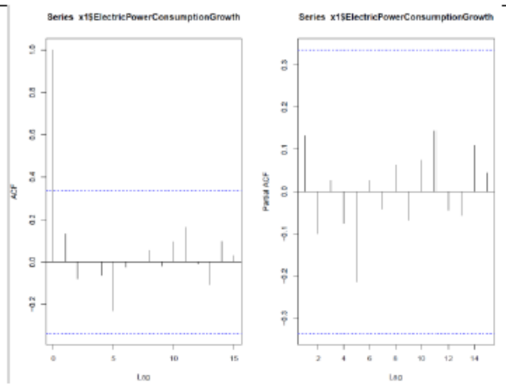
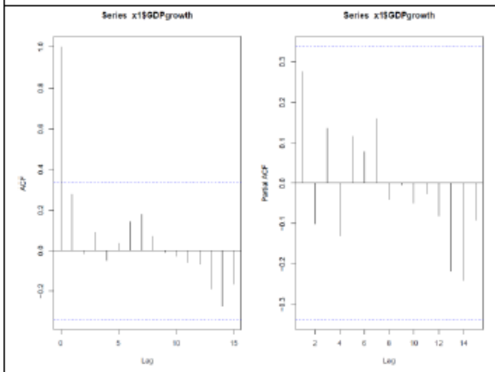
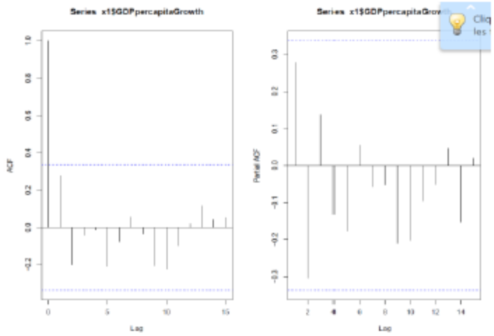
$y_t = c + \delta t + a\, y_{t-1} + e(t)$.

The null hypothesis restricts $a = 1$. Variants of the test, appropriate for series with different growth characteristics, restrict the drift and deterministic trend coefficients, c and δ, respectively, to be 0. The tests use modified Dickey-Fuller statistics to account for serial correlations in the innovations process $e(t)$.

```
> PP.test(x1$TradeGrowth, lshort = TRUE)

        Phillips-Perron Unit Root Test

data:  x1$TradeGrowth
Dickey-Fuller = -5.3882, Truncation lag parameter
= 3, p-value = 0.01

> PP.test(x1$GDPgrowth, lshort = TRUE)

        Phillips-Perron Unit Root Test

data:  x1$GDPgrowth
Dickey-Fuller = -4.8963, Truncation lag parameter
= 3, p-value = 0.01
> PP.test(x1$ElectricPowerConsumptionGrowth, lshort = TRUE)

        Phillips-Perron Unit Root Test

data:  x1$ElectricPowerConsumptionGrowth
Dickey-Fuller = -5.1674, Truncation lag parameter
= 3, p-value = 0.01

> PP.test(x1$GDPpercapitaGrowth, lshort = TRUE)

        Phillips-Perron Unit Root Test

data:  x1$GDPpercapitaGrowth
Dickey-Fuller = -3.9607, Truncation lag parameter
= 3, p-value = 0.02282

> PP.test(x1$GrossCapitalFormationGrowth, lshort = TRUE)

        Phillips-Perron Unit Root Test

data:  x1$GrossCapitalFormationGrowth
Dickey-Fuller = -6.6601, Truncation lag parameter
= 3, p-value = 0.01
```

Graphically, yields seem to oscillate around a certain value. The Phillips-Perron test confirms the stationarity of returns. However, it is too premature to state anything about the presence or not of white noise; a special case of a stationary process where not only the expectation but also all the covariances are zero - the box-Jenkins method will be used for further analysis.

- ✓ ***Verification of the normality of the residues:***

<table>
<tr><td colspan="2">Correlograms and Partial Correlograms (use of the AIC-minimization criterion)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Acceptable c(0,0,1)</td><td>Acceptable c(0,0,1))</td></tr>
<tr><td>
</td><td>
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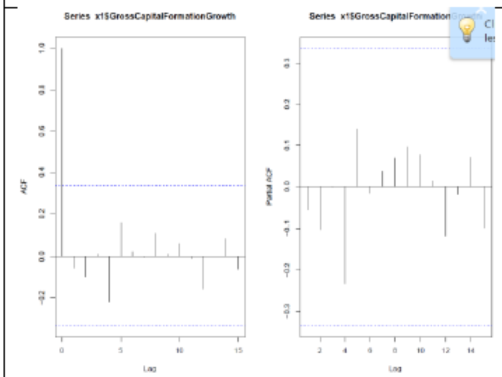
<tr><td>Acceptable c(0,0,1)</td><td>Acceptable c(0,0,1)</td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>Acceptable c(0,0,1)</td><td></td></tr>
</table>

Figure 4.3: Verification of the normality of the residues

It is assumed in multiple regression that the residuals (predicted minus observed values) are distributed normally. Again, even though most tests are quite robust with regard to violations of this assumption, it is always a good idea, before drawing final conclusions, to review the distributions of the major variables of interest. You can produce histograms for the residuals as well as normal probability plots, in order to inspect the distribution of the residual values.

As shown above, the residues are almost non-existent, thereby suggesting the normality hypothesis.

- ✓ ***R modelling (with Energy consumption as variable of interest):***

```
glm.D93 <- glm(x1$EnergyConsumptionGrowth ~ x1$GDPgrowth + x1$TradeGrowth+x1$GDPpercapitaGrowth + x1$GDPpercapitaGrowth + x1$GrossCapitalFormationGrowth,x1, family = gaussian())
> anova(glm.D93)
Analysis of Deviance Table

Model: gaussian, link: identity

Response: x1$ElectricPowerConsumptionGrowth

Terms added sequentially (first to last)


                               Df Deviance Resid. Df Resid. Dev
NULL                                              33     458.23
x1$GDPgrowth                    1   91.659        32     366.57
x1$TradeGrowth                  1    0.013        31     366.55
x1$GDPpercapitaGrowth           1    1.395        30     365.16
x1$GrossCapitalFormationGrowth  1   23.832        29     341.33
> summary(glm.D93)

Call:
glm(formula = x1$EnergyConsumptionGrowth ~ x1$GDPgrowth +
   x1$TradeGrowth + x1$GDPpercapitaGrowth + x1$GDPpercapitaGrowth +
   x1$GrossCapitalFormationGrowth, family = gaussian(), data = x1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-7.4794  -2.3320  -0.1061   1.6274   9.9802

Coefficients:
                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                    -1.81410    1.03740  -1.749   0.0909 .
x1$GDPgrowth                    1.02010    0.38725   2.634   0.0134 *
x1$TradeGrowth                 -0.01153    0.09974  -0.116   0.9088
x1$GDPpercapitaGrowth          -0.01111    0.05072  -0.219   0.8282
x1$GrossCapitalFormationGrowth -0.10921    0.07675  -1.423   0.1654
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The results indicate that only the GDP growth has a significant impact on the energy consumption.

Energy Growth= -1.81410 + 1.02010 GDP growth (Equation 1)

Based on equation 1, it can easily be concluded that the relationship between Energy and GDP is positive. However, the above results suggest that, from the period observed, there is no relationship between energy and trade, neither with energy and GDP per capita, and nor with energy and capital in South Africa.

- ✓ ***R modelling (with GDP growth as variable of interest):***

```
> glm.D93 <- glm( x1$GDPgrowth~ x1$EnergyConsumptionGrowth + x1$TradeGrowth+x1$GDPpercapitaGrowth + x1$GDPpercapitaGrowth + x1$GrossCapitalFormationGrowth,x1, family = gaussian())
> anova(glm.D93)
Analysis of Deviance Table

Model: gaussian, link: identity

Response: x1$GDPgrowth

Terms added sequentially (first to last)


                              Df Deviance Resid. Df Resid. Dev
NULL                                             33    167.939
x1$EnergyConsumptionGrowth     1   33.593        32    134.346
x1$TradeGrowth                 1   33.223        31    101.123
x1$GDPpercapitaGrowth          1   18.749        30     82.374
x1$GrossCapitalFormationGrowth 1   19.044        29     63.331
> summary(glm.D93)

Call:
glm(formula = x1$GDPgrowth ~ x1$EnergyConsumptionGrowth +
   x1$TradeGrowth + x1$GDPpercapitaGrowth + x1$GDPpercapitaGrowth +
   x1$GrossCapitalFormationGrowth, family = gaussian(), data = x1)

Deviance Residuals:
    Min        1Q    Median       3Q      Max
-2.94845  -0.57990  -0.04228   0.87139   2.43753
```

```
Coefficients:
                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                     2.07170    0.26970   7.681 1.81e-08 ***
x1$EnergyConsumptionGrowth      0.18927    0.07185   2.634  0.01339 *
x1$TradeGrowth                  0.12122    0.03661   3.311  0.00249 **
x1$GDPpercapitaGrowth           0.04016    0.02055   1.954  0.06046 .
x1$GrossCapitalFormationGrowth  0.08854    0.02998   2.953  0.00618 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

GDP growth = 2.071 + 0.189 Energy growth + 0.121 Trade growth + 0.088 Capital growth (Equation 2)

The results indicate that Energy Consumption, trade and capital formation have significant impacts on GDP growth. Evidence from equation 2 suggests that there is a positive relationship between GDP, as the variable of interest, and energy consumption, trade and capital. In other words, GDP depends largely on energy consumption, trade and capital. Hence GDP growth could also be achieved by increasing trade and/or capital without necessarily changing the energy consumption.

4.5 FINDINGS

Equation 1 clearly demonstrates that, in the context of this study with its limitations, energy is solely dependent on GDP. Equation 2, though, established that GDP depends not only on energy but also on trade and capital. Despite the limitations presented in this study in respect to the non-exhaustive nature of the influencing interim variables selected, there is strong evidence from equation 1 and 2 of the asymmetric character of the relationship between GDP growth and energy consumption. However, there is no prevailing evidence in this study on the direction of causality between the two variables of interest.

On the other hand, academic studies propose four different energy consumption and economic growth hypotheses. These are the ‘conservation hypothesis’, the ‘growth hypothesis’, the ‘feedback hypothesis’ and the ‘neutrality hypothesis’. Results from this study (equations 1 and 2) suggest that a conservation hypothesis is the most prevailing theory on the causal link between GDP and energy consumption in South Africa. This suggests that it is the economic growth that drives electricity consumption.

This view is known as the growth-led electricity consumption view. In this case, it is believed that electricity demand is driven largely by the economic growth of the real sector. Therefore, South Africa may not necessarily need electricity for its economic growth and this is clearly demonstrated in equations 1 and 2. From equation 2, although energy consumption has a major influence on economic growth, this could also possibly be achieved by increasing trade and/or capital, without any change in energy consumption. Hence, energy conservation policies could be implemented with little or no adverse effects on economic growth.

4.6 SUMMARY

This chapter started by discussing rationalities for excluding electricity prices and labour from raw data. This was the most viable trade-off solution option to increase reliability by allowing for a greater span period for historical data. Raw data were extracted from World Development Indicators.

Data were then processed through R programming with the view to analyse trends which suggest that only economic growth seems to follow a stationary evolution. Thereafter, data were prepared and transformed with the view to describe one variable based on another. Transformation was a critical path of this methodology process since it reduced the volatile nature of variables.

Using energy consumption as a variable of interest, results indicated that economic growth has a significant impact on energy consumption through a positive relationship. However, results also revealed that, from the period observed, there is no relationship between energy and trade, neither with energy and GDP per capita, and nor with energy and capital in South Africa.

Using economic growth as a variable of interest, results indicated that Energy Consumption, trade and capital formation have significant impacts on GDP growth. In addition, results further suggested that there is a positive relationship between GDP, as the variable of interest, and energy consumption, trade and capital.

In combining the two results, a conservation hypothesis was found to be the most prevailing theory on the causal link between GDP and energy consumption in South Africa. The next and final chapter will discuss conclusions and recommendations.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study is to to investigate the asymmetric relationship between energy consumption and economic growth in South Africa using non-linear autoregressive distributed lag bounds approach.

We presented in chapter 1 of this thesis the concepts of economic growth and electricity consumption within the global and South African context. The chapter started with an overview highlighting the vital role played by electricity in all economies. It emphasised its large multiplier effect generated through its contribution to the enlargement of the primary, secondary and tertiary sectors of the economy. The chapter further discussed global energy trends and scenarios; and highlighted the competing view on the relationship between economic growth and electricity consumption. Focus on the chapter was then narrowed on the energy consumption profile in Africa by looking at demography, energy consumption, the need for new strategy for the continent, energy supply, and finally looking particularly at the South African context.

In chapter 2, under literature review, we reviewed current studies conducted globally, regionally and nationally on the relationship between economic growth and electricity consumption. Literature suggests that recent growing concerns on climate change have further prompted the interests of many researchers to examine the relationship between electricity consumption and growth in the economy. Results from case studies from numerous countries suggest that there is still persistent disagreement on the relationship between electricity and growth. This is largely attributed to the a high level of sensitivity to countries of choice, sample period and methodology applied. In addition, the numerous conflicting findings from various studies in literature suggest that the relationship between economic growth and electricity consumption depends on other variables that play a pivotal role. Taking into account the various literatures, the kernel of this research lies in its originality by investigating the asymmetric relationship between electricity consumption and growth through a multivariate framework including the following intermediary variables: trade openness, electricity prices, capital and employment.

In chapter 3, we contextualised and defined all variables under in this research. These variables are energy consumption, economic growth, electricity prices, trade openness, capital, and labour. A methodology process was then explained using a model from Grolemund and Wickham (2017). The model consisted of providing a simple low-dimensional summary of dataset and methodology process through import, data tidying, transformation, statistical modelling, and communication. Thereafter, the chapter focussed on the approach used for sampling, population identification as well as ethical considerations. Finally, R programming was introduced to explain why it was the preferred tool for this research and what it could possibly achieve.

In chapter 4, we started by discussing rationalities for excluding electricity prices and labour from raw data. This was the most viable trade-off solution option to increase reliability by allowing for a greater span period for historical data. Raw data were extracted from World Development Indicators. Data were then processed through R programming with the view to analyse trends which suggested that only economic growth seems to follow a stationary evolution. Thereafter, data were prepared and transformed with the view to describe one variable based on another. Transformation was a critical path of this methodology process since it reduced the volatile nature of variables.

Using energy consumption as a variable of interest, results indicated that economic growth has a significant impact on energy consumption through a positive relationship. However, results also revealed that, from the period observed, there is no relationship between energy and trade, neither with energy and GDP per capita, and nor with energy and capital in South Africa.

Using economic growth as a variable of interest, results indicated that Energy Consumption, trade and capital formation have significant impacts on GDP growth. In addition, results further suggested that there is a positive relationship between GDP, as the variable of interest, and energy consumption, trade and capital.

In combining the two results, a conservation hypothesis was found to be the most prevailing theory on the causal link between GDP and energy consumption in South Africa.

Conclusions:

As concluding remarks, this study reveals an economic perspective, without necessarily expanding energy accessibility, trade liberalisation and capital could generate clear gains to South Africa and efforts to promote and accelerate these initiatives should be encouraged. Given the often-competing resource limitation challenges faced by the South African government, as a result of prioritisation, trade liberalisation should be favoured and be given roughly in the range of 1.5 times more attention than capital.

Meanwhile, although relationships could be fully ascertained using regression techniques, the major conceptual limitation lies on the underlying causal mechanism. In this study, there is a strong positive relationship between energy consumption and economic growth but it cannot be concluded with a high level of confidence that any form of growth in the economy leads to increased energy consumption or vice versa. Of course, the most likely explanation of this correlation is that the size of economy impacts on energy consumption and/or vice versa but the sensitivity of such a relationship still requires further investigations given that there are many influencing factors.

Finally, contrary to a popular opinion, it is no longer imperative to reduce the energy constraints of companies and households in order to accelerate economic development.

Recommendations:

1. As a result of prioritisation with government initiatives, trade liberalisation should be favoured and be given roughly in the range of 1.5 times more attention than capital; and
2. Sustained efforts are rather needed to strengthen regional integration with the view to progressively achieve trade liberalisation and increase capital formation. Subsequently, continued efforts are also needed to strengthen regional cooperation in energy policies with a view to achieve greater synergy in the sector.

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